Carroll Barrell
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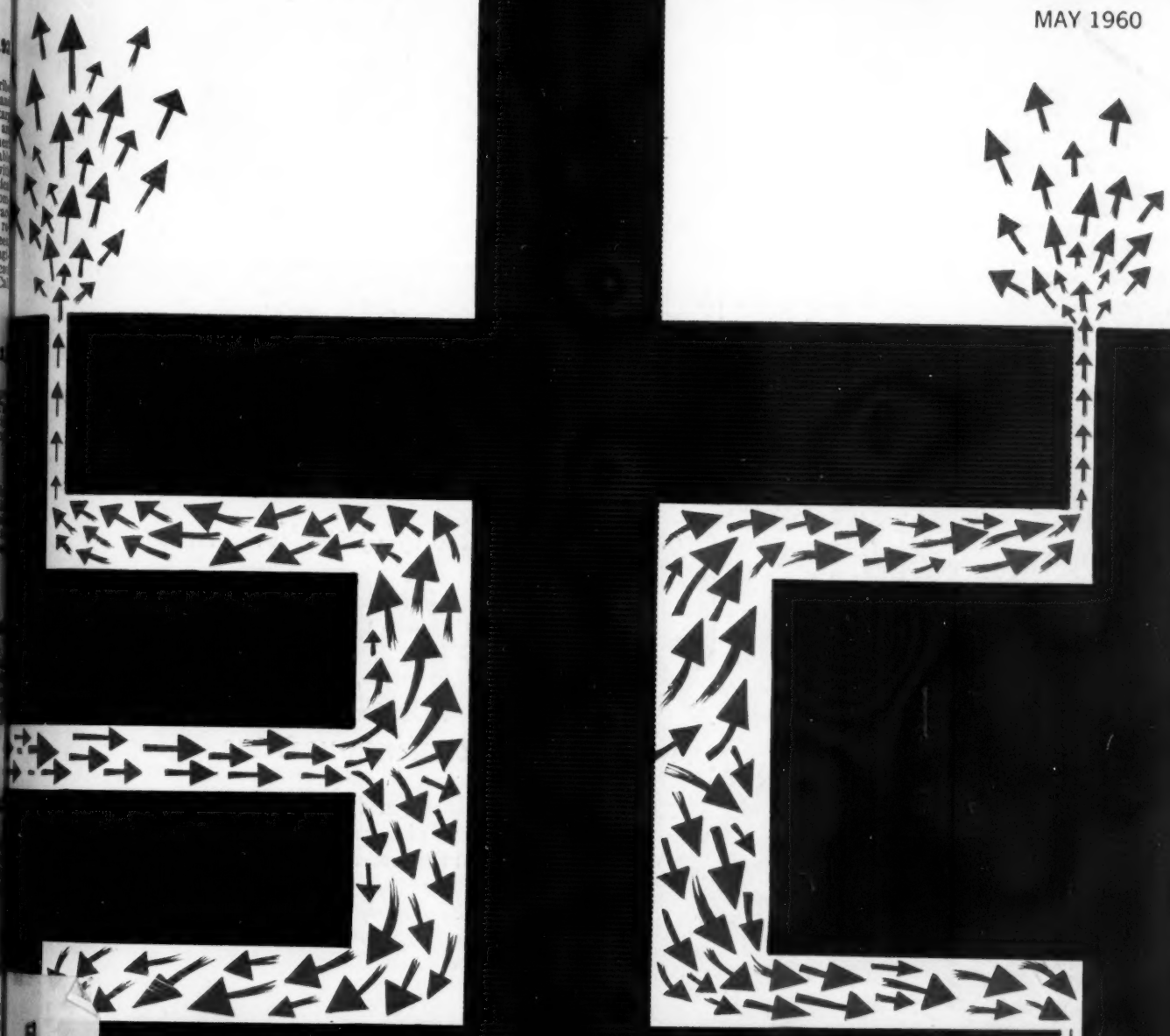
ELECTROMECHANICAL components & systems DESIGN

MAY 1960

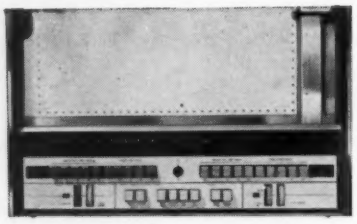


FLORA

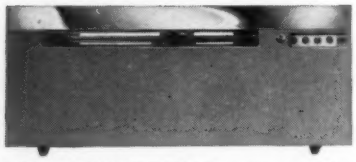
AIR SUSPENSION TORQUE TESTER

measures torque well below 1/10 dyne centimeter

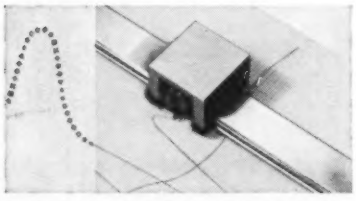
R. Carroll, Asst. Dir.
The University of Michigan
Ann Arbor, Michigan
Mech. Eng.



PUSH BUTTON PANEL controls operations rapidly, even at remote locations.

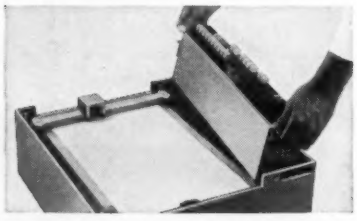


FLAT VACUUM PLATEN assures positive hold down of roll or sheet paper up to 12¼" width. Plot area, standard 10x15".

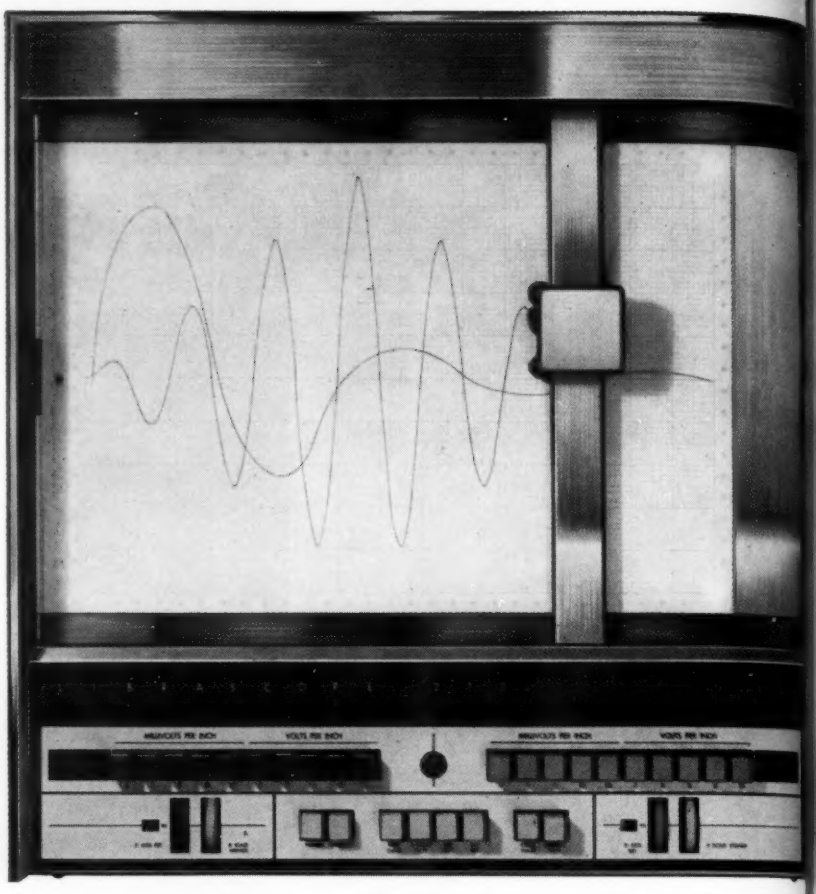


PRINTING FEATURES: Multiple symbol printing head—12 symbols...self contained ink supply.

Pen System—capillary action; splatter-proof. Point joiner available.



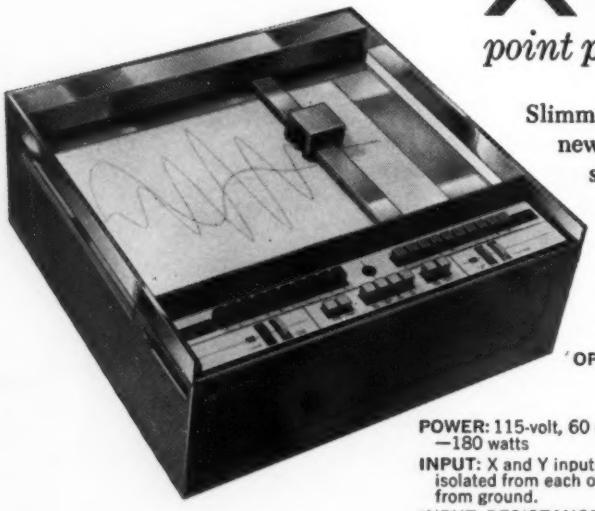
INTERCHANGEABLE MODULES add versatility...interchange with basic control section.



engineered for ease of operation...new

LIBRASCOPE X·Y PLOTTER

point plotting or continuous trace



Slimmer, flatter, push-button fast...Librascope's newest, most advanced plotter is the result of personally-conducted field research by Librascope engineers. Compact design permits rack mounting in groups, saves desk space. Many new conveniences have been added to answer *your* needs.

OPERATING INFORMATION

POWER: 115-volt, 60 cycle —180 watts

INPUT: X and Y inputs isolated from each other and from ground.

INPUT RESISTANCE: 2 megohms nominal on most scales. 1 megohm per volt on .5 millivolts per inch to .1 volts per inch scales.

INPUT SENSITIVITY: .5 millivolts per inch to 50 volts per inch with calibrated push button scales at .5, .1, 5, 10 and 50 millivolts per inch and .1, .5, 1, 5 and 10 volts per inch. Vernier controls permit continuous sensitivity adjustment between fixed scales, permitting full scale plotting for any sensitivity.

ACCURACY: Static .1%, dynamic .2% at 10" per second.

PLOTTER CALIBRATION ACCURACY: .05% on all scales.

SLEWING SPEED: 20" per second.

For full details — dimensions, applications, list of accessory equipment, call our Sales Engineering Department or send for illustrated brochure on Model 210, XY Plotter.

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

LIBRASCOPE division **GENERAL PRECISION, INC.** • 808 Western Ave., Glendale, Califor

CIRCLE NO. 1 ON INQUIRY CARD

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

MAY 1960 • VOL. 4 NO. 5

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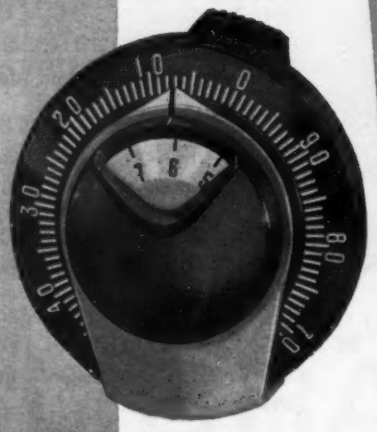
NEW



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Now from Borg, originator of famous Microdials, comes a fresh, new concept in turn-counting dial appearance . . . Series 1360 Microdials. These new Borg Microdials were specially developed to add style and color to electronic control panels and equipment. Available in five smart models of red, gray and black color variations. Colors are inlays of colored plastic . . . will never wear, scale or rub off. Quality mechanical features such as smoothness of action . . . absence of noise . . . fewer ambiguities in reading and setting assure accurate, reliable performance. Contoured brake arms lock settings in place, but do not interfere with reading and setting. Catalog data sheet BED-A137 gives complete color combinations and specifications. See your Borg technical representative or distributor, or let us put him in touch with you.

BORG®

BORG EQUIPMENT DIVISION

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Janesville, Wisconsin

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CIRCLE NO. 2 ON INQUIRY CARD

ELECTROMECHANICAL
components & systems DESIGN

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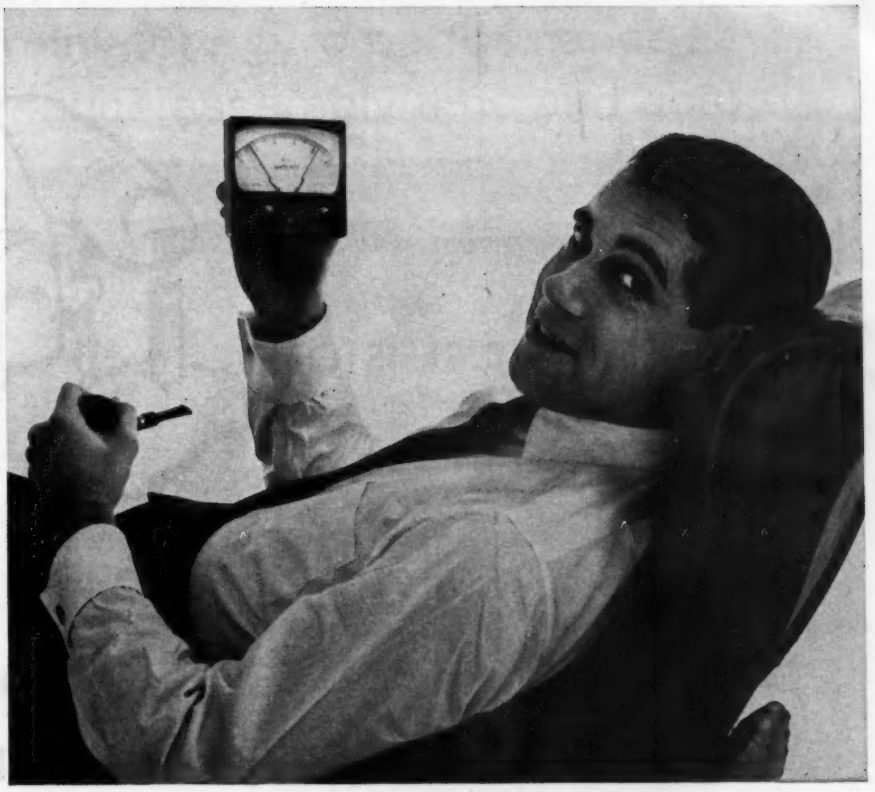


STOP WORRYING

the API meter-relay offers fully reliable control —at low cost... thanks to the locking coil

There was a time when engineers went to far more complicated devices for peace-of-mind control reliability. Now, with nerve-saving dependability and money-saving simplicity, the API meter-relay does an even better control job.

Reliability of the meter-relay (in fact, growth of this entire company) stems from one beautifully executed idea: the API locking coil.

This unique locking coil gives "yes-no" decisiveness to the highly-sensitive D'Arsonval meter. Responding to any type or most any magnitude of input signal, the API meter-relay is able to provide firm control action . . . and do it at least 10 to 20 million times. What other electrical device offering such sensitive discrimination can give this service?

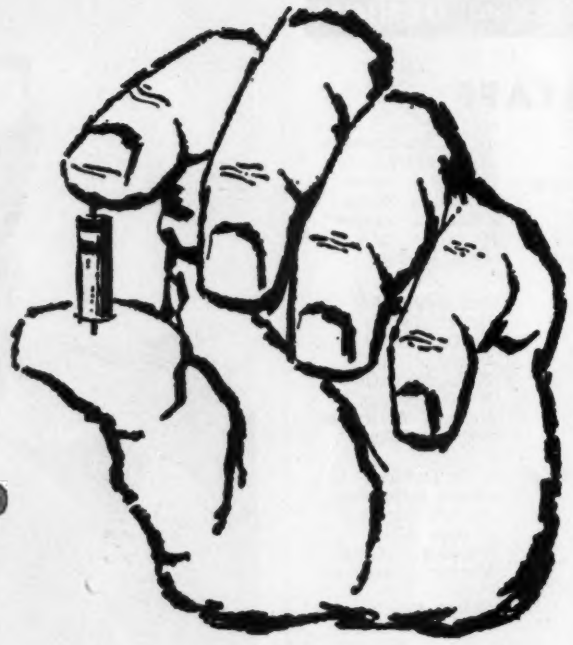
Your control, regulating, monitoring and, perhaps, cost problems may be solved by the API meter-relay. It is certainly worth sending for our "HOW and WHY" booklet and catalog. Ask for Bulletins S-1 and 4-G.

api **ASSEMBLY PRODUCTS, INC.**
Chesterland 79, Ohio

SA 2164

CIRCLE NO. 3 ON INQUIRY CARD

A 1-WATT RESISTOR BECOMES A VOLTAGE STANDARD WHEN USED WITH A ®REGATRON PROGRAMMABLE POWER SUPPLY

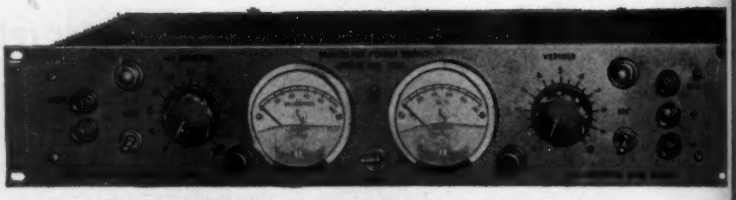


Take a 1-watt resistor. Place it across the programming terminals of a Regatron Programmable Power Supply. Instantly you've fixed the output voltage to 1/1000 of the resistance value. For example, a 22.5K resistor will fix the output at 22.5V. For a perfect repeat every time, use the same resistor. For other voltages use a different resistor. The output will always equal 1/1000 of the resistance value.

In addition, you'll find that Regatron Programmable Power Supplies have all the other advanced features you would expect in a versatile laboratory instrument; super-regulation, vernier as well as main voltage control, and more. Compare a Regatron Programmable Power Supply with any other d-c power source, batteries included. You'll find you won't settle for less.

Regatron Programmable Power Supplies are available in voltage ranges covering 0-50 V dc, 0-100 V dc, 0-300 V dc, and 0-600 V dc. Current ratings are up to 3A, depending on model. Request Bulletins 350 and 765.

(Various models without the programming feature are also available in voltage ranges up to 1000 V and currents up to 1 ampere.)



TRANSISTOR TYPES

MODEL NUMBER	OUTPUT		REGULATION				MAXIMUM RIPPLE IN MV
			LINE 105—125 V AC 50—60 CPS		NO LOAD TO FULL LOAD		
	Voltage	Current	%	V	%	V	
212A[1]	0—100 V DC	0—100 MA	0.15	0.05	0.1	0.05	½
2-212A[1]	EQUIVALENT TO TWO MODEL 212A's. OUTPUTS MAY BE USED IN SERIES, PARALLEL, OR INDEPENDENTLY.						
224A[1]	0—100 V DC	0—200 MA	0.15	0.05	0.1	0.05	1
220A	0—50 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
221A	0—100 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
213A	0—50 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
214A	0—100 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
215A	0—50 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1
218A	0—100 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1

1. Modulation input provided for measurement of transistor parameters by small signal method.

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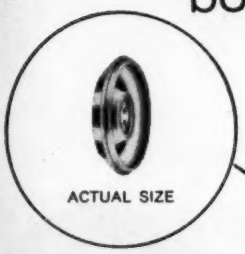
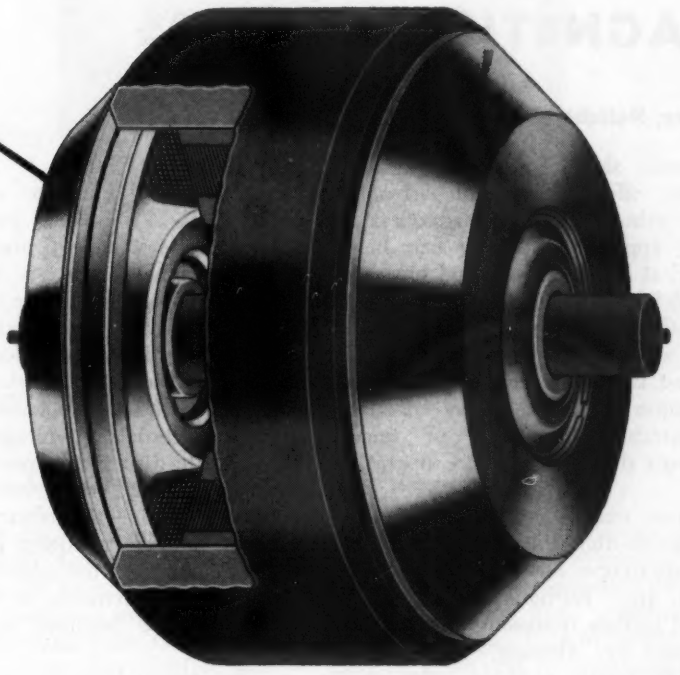
ELECTRONIC MEASUREMENTS COMPANY, INCORPORATED
EATONTOWN • NEW JERSEY

CIRCLE NO. 4 ON INQUIRY CARD

BARDEN end-bell bearings boost miniature gyro performance– reduce assembly time and cost





Integral design simplifies manufacture, reduces mating-part errors

Z155, *above and in main illustration,* is one of several Barden Precision end-bell bearings currently in volume production. Bore sizes range from .0781" to .1250" for through-bored rotor rings from .5751" to .9375" I.D. For complete technical information, write for Engineering Data Sheet Z-1.

Rotor bearings for miniature rate gyros in missile stabilizing systems must meet extremely high performance requirements, yet allow economical production and assembly. To solve this problem, Barden pioneered special configuration, high precision end-bell bearings.

Pressed into opposite sides of the through-bored rim, these bearings become an integral part of the gyro spin mass while serving as end caps for the gyro wheel assembly. This eliminates delicate fitting of very small bearings into conventional end bells . . . reduces mating-part errors and assembly time . . . improves squareness, concentricity, and overall accuracy and reliability.

One gyro manufacturer reports that the use of Barden Precision end-bell bearings in place of conventional flanged bearings reduced noise levels 50% and made it possible to meet unusually stringent life requirements.

Like other Barden advances in design and production, end-bell bearings solve a specific performance problem. Other Barden Precision bearings satisfy such extreme demands as:

- High temperatures (to 575°F.)
- High speeds (to over 300,000 RPM)
- Low torque (to 10 dyne-cm. for 2 lb. load)
- Concentric rotation (to .00005" max. T.I.R.)

Barden is a major supplier of standard bearings in sizes from .0469" bore to over 3" O.D., all manufactured to Barden Precision standards of dimensional accuracy, uniformity and reliability. See Sweet's Product Design File (8h/Ba) for Barden catalog and bearing selection guide.

for reliability... specify **BARDEN PRECISION BALL BEARINGS**

THE BARDEN CORPORATION, 206 Park Avenue, Danbury, Connecticut
Western Office: 3850 Wilshire Boulevard, Los Angeles 5, California

CIRCLE NO. 15 ON INQUIRY CARD

MAGNETIC ENCODERS

Faster, Reliable Shaft Angle-To-Digital Conversion

Magnetic shaft position-to-digital encoders offer substantial advantages over other types of encoders for many applications. They can be operated at higher speeds and have a potential life exceeding 20,000 hours. Inherently more rugged and reliable, their service life is limited only by bearing life. The noncontact magnetic technique eliminates any need for mechanical adjustment of encoder elements during the entire operational life.

A new magnetic technique for shaft position-to-digital encoders, developed by Librascope Division, General Precision, Inc., Burbank, Cal., generates digital signals representing input shaft position by altering the magnetic state of ferrite readout cores in accordance with a coded pattern cut into the surface of a ferrite disc driven by the input shaft.

The coded pattern, consisting of raised and depressed portions corresponding to the "zero" and "one" states of the binary bits, is ultrasonically machined on the surface of the ferrite disc. The readout cores and the ferrite disc are placed in close proximity within a section of a static magnetic field and the ferrite cores are excited by an alternating voltage source. As the ferrite disc rotates past the readout cores, magnetic induction of the cores is altered in accordance with the coded pattern, resulting in an impedance change of the core with respect to the other elements in the excitation circuit and a bivalued voltage across the core.

The toroidal ferrite cores are approximately 0.100 inch in outside diameter and 0.070 inch in inside di-

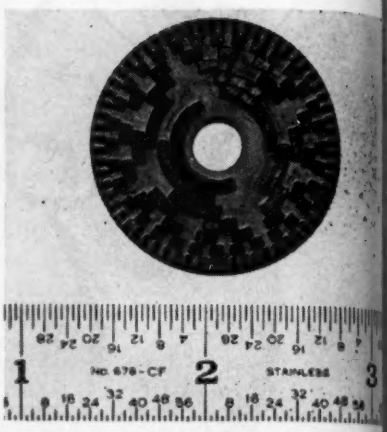


Fig. 2 The coded pattern on the surface of the ferrite disc is produced by ultrasonic machining. Concentric tracks of raised and depressed portions correspond to the binary bits used in the digital representation of the shaft position. In a 7-bit encoder which can resolve a shaft revolution to one part in 128, seven concentric tracks are required. Depressed portions of the pattern correspond to the binary "one" and raised portions correspond to the binary "zero".

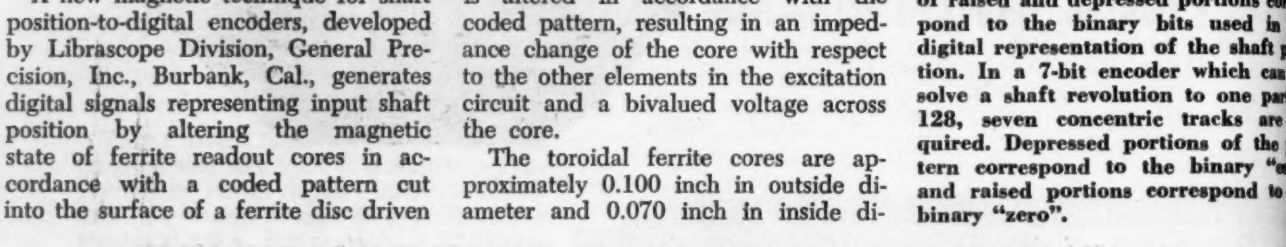


Fig. 1 Basic operating principles of the Librascope magnetic encoder technique are shown in this illustration. The ferrite readout cores and the ferrite code disc occupy the air gap between the ends of the magnetic housing. The field is generated by a field coil fixed to one end of the magnetic housing. Total flux density within the readout core results from the flux generated by its own excitation current and the flux of the core-encompassing magnetic circuit. Polarities of the two fields are arranged so that action of the fixed field magneto-motive force is to oppose the core's excitation field's magneto-motive force. When a depressed portion of the code disc track, corresponding to a binary "one", shares the air gap with the core, the fixed field flux density is decreased because of the increase in magnetic circuit reluctance. This results in an increased magnetic induction in the core and an increased impedance. Voltage drop across the core is increased so that the output voltage is high corresponding to a binary "one". Conversely, when a raised portion of the code disc shares the air gap with the core, the fixed field flux density is increased because of the decrease in magnetic circuit reluctance. The resultant magnetic induction in the core is decreased and the core impedance decreased. Voltage drop across the core is decreased so that the output voltage is low corresponding to a binary "zero".

Fig. 3 Incorporated in Navy fire control systems, Librascope's magnetic encoders have operated successfully for over 20 million revolutions, at 1000 rpm.

ameter. Driving current and number of turns of the winding are fixed at values required to drive the core to magnetic saturation just before the completion of each half cycle of the driving signal, assuring maximum reliability of core switching. The driving circuit consists of the alternating current source, a fixed resistor, and the core.

Librascope has applied this magnetic technique successfully to 7-bit, 13-bit, 17-bit, and 19-bit encoders. Input shaft speeds as high as 10,000 rpm can be accommodated by the 7-bit encoder. Speeds of 3,000 rpm are possible with the higher capacity units. Additional sizes and capacities are planned for introduction later.

The magnetic encoders can be supplied with a wide range of digital codes including true binary, Gray, and binary coded decimal. The Librascope-developed V-scan technique is used to prevent ambiguity of readout when binary codes are used.

Excellent one-zero voltage ratios inherent in the new technique permit use of a wide variety of reliable readout circuits. Magnetic encoders may be used singly or in multiplexed combinations, and readout may be in serial or parallel form. Up to 20 encoders may be linked by a single-harness transmission system and excited by a single a-c source. Sequential or random interrogation by a single set of decoding circuits is thus possible.

Circle No. 107 on Inquiry Card

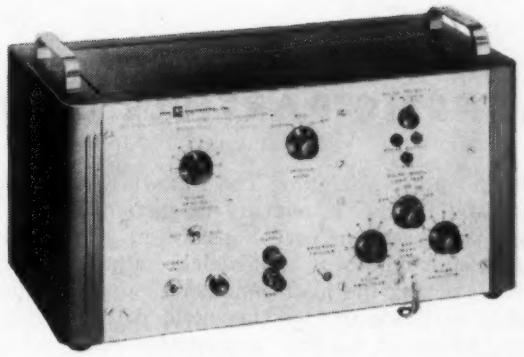


Fig. 1 Rese Engineering's Millimicrosecond Current Pulse Generator.

MILLIMICROSECOND PULSE GENERATOR

4 Amp Jitter-Free Pulses For High Speed Magnetic Studies

High amplitude, ultra-short current or voltage pulses for analysis of high speed logic and memory problems and solid state switching are delivered by a Millimicrosecond Pulse Generator developed by Rese Engineering, Philadelphia, Pa. Producing jitter-free positive or negative pulses at widths ranging from 10 to 100 millimicroseconds, the unit generates current amplitudes as high as 4 amps, particularly effective for high speed ferrite core analysis and studies of multi-apertured ferrite devices. Rise time of less than 5 millimicroseconds at moderate currents makes the instrument especially suitable for thin magnetic film development and basic magnetic switching research.

Any one of the four fixed pulse widths, 10, 20, 50 or 100 millimicroseconds, may be selected from a front panel control. The control connects one of four coaxial transmission lines to the plate of a thyratron, which, when triggered, discharges the line generating the fixed width pulse. Pulses of intermediate or longer widths may be generated by connecting an external delay line to a front panel connector. Pulse repetition frequencies range from 50 to 5,000, continuously variable through two ranges.

Unit operates either synchronously, using an internal clock, or asynchronously from an external trigger source. Effective multi-megacycle operation, in pulse bursts, can be achieved by triggering two or more generators from a multiple output, phased source. A sync pulse occurring 0.25 microseconds before the main pulse output and the brighter trace of the 5 kc waveform facilitates oscilloscope indication of the generated pulse and load response.

Circle No. 109 on Inquiry Card

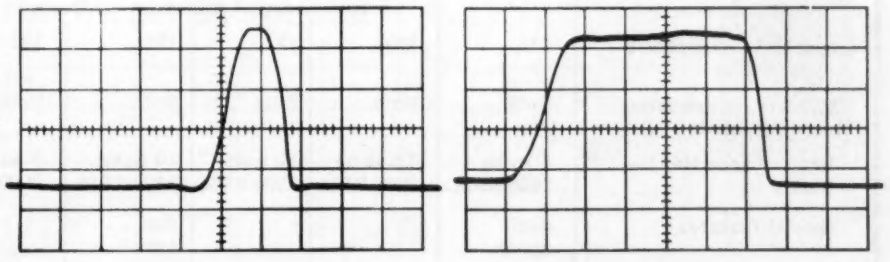


Fig. 2 Left waveform is a 100 μsec negative 4 amp pulse and right is a 20 μsec negative 4 amp pulse.

DRY MAGNETIC-PARTICLE CLUTCHES

Components Digest 13 "Miniature Magnetic Clutches and Brakes" in our March, 1960 Issue was based in part on answers to a questionnaire sent to manufacturers. In organizing the information, we found it advisable to limit the subject matter to units of the friction disc type. One respondent, the Electromechanical Division of Lear, Inc., submitted answers that apply to dry magnetic-particle clutches. These answers are sufficiently informative to warrant their separate publication exactly as submitted in question and answer form.

The following comments refer only to dry magnetic-particle clutches. Torque transmission is affected as a result of magnetic attraction acting across an annular air gap partially filled with dry magnetic particles. These clutches do not contain axially-moving parts.

1. *What are your principal performance problems?* Heat generated mechanically due to clutch slip when overloaded. Residual drag when only one clutch is used as a disconnect and very low drag is desirable, or when a pair of clutches is used in an open-loop servo.

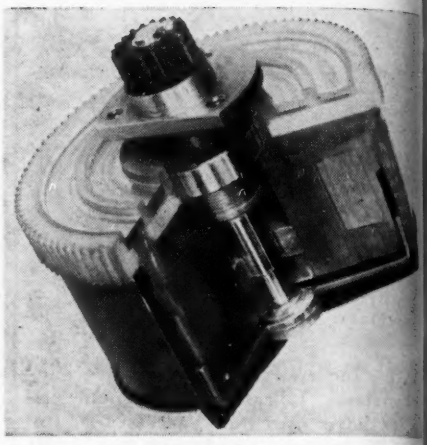
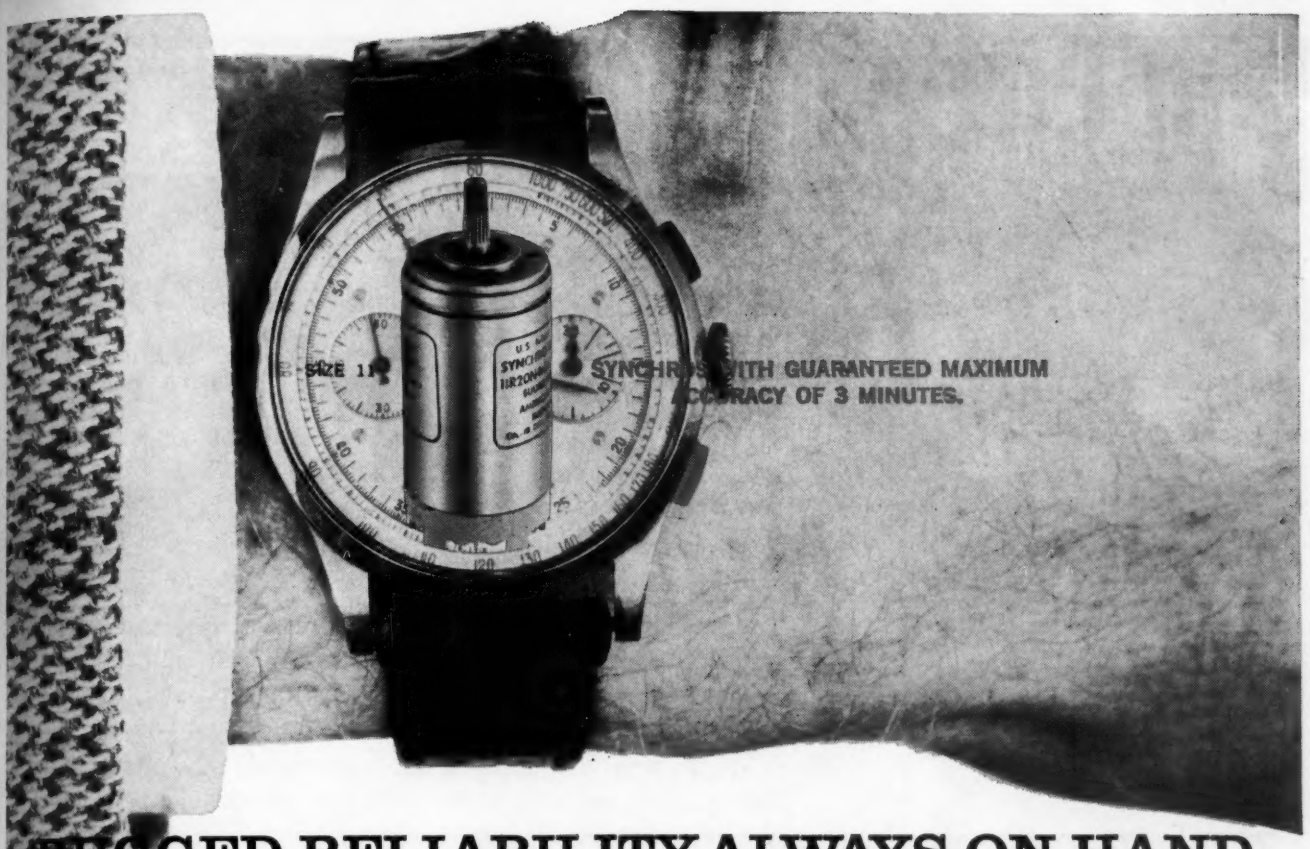


Table of Characteristics

Type or Model Number	877	878	890	891	892	900	909	917
Type of Unit	DRY MAGNETIC PARTICLE							
Diameter (inches)	1.16	3.16	1.61	1.68	1.16	2.02	10	3.06
Length (inches)	2.55	3.9	2.0	3.58	1.92	2	6	3.8
Nature of engaging surfaces	DRY MAGNETIC PARTICLE							
Electrical power for rated torque (watts) [1]	.5	1	.7	.7	1	1	13	2
Rated torque (ounce-inches)	12	560	32	48	12	128	16,000	1920
Inertia (gm-cm^2) [2]	4.5×10^{-6}	2.37×10^{-4}	9×10^{-6}	9×10^{-6}	4.5×10^{-6}	5.7×10^{-5}	.1	8.5×10^{-4}
Speed of response (seconds) [3]	.015	.025	.015	.015	.015	.020	.050	.040
Zero excitation torque (ounce-inches)	3.2	2	3	3	1.5	3.2	320	24
Life (please define conditions exactly) [4]	5000 hours at zero slippage (zero mechanical heat dissipation) 1000 hours at maximum continuous dissipation							
Ambient temperature limits (°C) [5]	121	150	121	121	121	121	121	121
Military or industrial environments	Both	Both	Both	Both	Both	Both	Both	Both
Performance limitations [6]	5 watts 2000 RPM	75 watts 3400 RPM	10 watts 2500 RPM	10 watts 2500 RPM	5 watts 2000 RPM	15 watts 2000 RPM	500 watts 1000 RPM	60 watts 1500 RPM
Special features	dual clutch			dual clutch				
Unusual application								

1. D. C. watts are listed.
2. Inertia of output shaft is listed in lb-in. sec^2.
3. Values obtained from pentode source excitation.
4. General values listed. Exact life is function of application.
5. Upper limit shown. Clutches practically unaffected by lower limit.
6. Continuous mechanical heat dissipation at maximum recommended speed.

Manufacturer - Lear, Incorporated, Electro-Mechanical Division



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SIZE 11 ELECTRICAL DATA

	11E22M-81G (Transformer)	11E22M-01F (Transmitter)	11E22-81J (Differential)
PRIMARY	Stator	Rotor	Stator
INPUT (VOLTS)	11.8	115	11.8
TEST (VOLTS)	10.2	115	10.2
FREQUENCY (CPS)	400	400	400
Z_{RO} ROTOR IMPEDANCE (STATOR OPEN CIRCUITED) (OHMS)	3340 /79°	2000 /80°	107 /78°
Z_{SO} STATOR IMPEDANCE (ROTOR OPEN CIRCUITED) (OHMS)	570 /80°	18 /79.5°	92 /80°
MAX. NULL VOLTAGE (FUNDAMENTAL) (VOLTS) (TOTAL) (VOLTS)	.030 .040	.015 .020	.015 .020
MAXIMUM ERROR (MINUTES)	3	3	3
TRANSFORMATION RATIO (R/S) ±4%	2.203	.103	1.154
PHASE SHIFT (DEGREES)	5	6	6
D. C. RESISTANCE (OHMS) STATOR ROTOR	60 385	3 185	11 19.0

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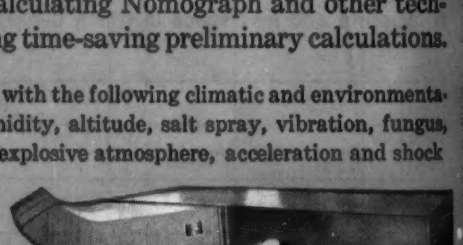

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CIRCLE NO. 17 ON INQUIRY CARD

How do you go about solving them? Specific details on critical applications are requested, such as: time history of clutch loading, life required, and ambient temperature. For severe applications, special high-temperature materials are used in coil winding and potting compounds. For residual drag, the quantity of powder and the air gaps may be varied; seal drag has been reduced to a practical minimum. When a pair of clutches is used in a servo, actuator drag may be equalized by carrying a quiescent current; for rapid stopping where back-driving torque is not critical, a constant friction load may be applied to the output to overcome residual drag. For closed-loop servo operation this residual drag is not a significant factor. Residual drag generally is about 3 ounce-inches.

2. *How do you define response time and what means do you employ for measuring it?* Response time is defined as being that time it takes for the clutch to develop 63% of maximum torque when excited with a step input equivalent to maximum current excitation. Impedance of the input source also must be specified, since response time varies significantly with source impedance. Response time is independent of speed. Response time is measured using an oscillograph recorder and a torque cell. The clutch is driven at a specified speed and excited from a specified source, generally a pentode. Excitation current and torque cell output are recorded versus time.

What does the clutch designer do to minimize response time? What can the user do? The clutch designer strives to achieve the highest possible torque-to-inertia ratio. This has been achieved in the Lear dry magnetic particle clutch; typical value of torque-to-inertia ratio achieved is 200,000 rad/sec^2. Final in-service results are achieved by close coordination between clutch designer and user. This coordination involves source impedance, clutch impedance, level of quiescent current permissible and proper rating of the clutch for specific load conditions.

3. *How do you solve problems related to the engaging faces? Such problems as: type of finish, effects of wear, oxidation, traces of oil or other contaminants or surface, etc.* These problems are virtually eliminated for dry powder clutches as compared to friction types. Finishes are compatible with good machining practices; and there is no practical evidence of wear (clutches have been run 5,000 hours and have accumulated 50,000,000 cycles without evidence of wear). Patented processes for the powder have eliminated oxidation problems with it. External clutch surfaces have protective finishes. Parts are vapor decreased prior to assembly, and the powder cavity is sealed. Seals are provided to prevent entry of oils or other contaminents into the working gap.

4. *How do you define "life" very accurately in terms of test procedures, exact operating conditions, duty cycle, etc.?* Life is defined in terms of duty cycle hours under specified load (including inertia) cycling, temperature, clutch excitation, altitude and humidity. Life expectancy will vary with the many combinations of these factors.

5. *What are the principle limits to clutch reliability?* Seals, bearings and brushes (where rotating coils are specified). Multiple seals are used for long-life applications or for jobs requiring greater than average reliability.

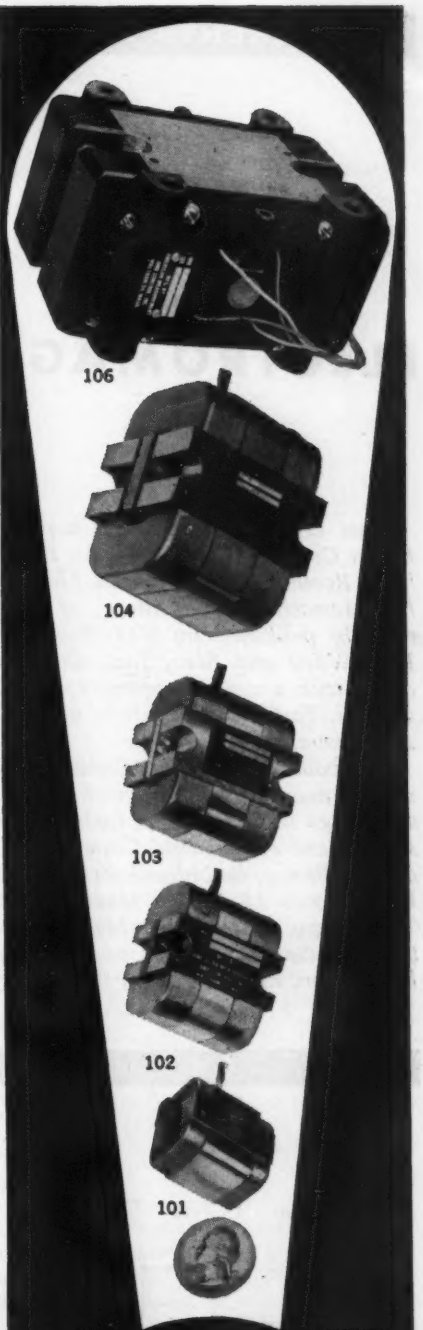
6. *What are the principal environmental problems and limits? What factors do you consider in design for maximum performance in severe environments?* Principal environmental problem is temperature, and state-of-the-art indicates designs are currently limited to ambient temperature of 450°F. Radiation is also a recognized problem, but clutches of this type have not been fully evaluated in this regard. Factors most significantly affecting performance in severe environments are load cycling and, specifically, amount of mechanical energy to be dissipated due to slippage.

7. *What new design advances do you anticipate in the future?* Development of a line of clutches utilizing stationary coils intended primarily for industrial use. These clutches to be made in various sizes from 1 lb-in. to 500 HP. Extension of ambient temperature limit for general application from 450°F to 600°F.

8. *Have you found any new applications for these clutches?* Business machines and data processing machines requiring an extremely large number of engagements and disengagements, also tensioning devices that require smooth chatter-free slip operation.

9. *What is the relative dollar volume for these clutches in the United States? Is the volume growing or diminishing?* $1-2 million per year, growing.

Circle No. 103 on Inquiry Card



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Stroking Radius (in.)	0.650	0.593	0.750	0.906	1.250
Midposition Force (lbs)	2.5	5.0	8.0	13.0	15.0
Hysteresis (%)	2	2	2	2	2
Resonant Frequency (cps)	950	775	600	400	250
Weight (oz.)	3¼	6	10	22	55

*Rotary output, dry-coil and high temperature models available.

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ELECTROMAGNETIC ACTUATORS PART TWO

This article taken from Chapter II of "Fluid Power Control", edited by John F. Blackburn, Gerhard Reethof and J. Lowen Shearer, copyrighted by Massachusetts Institute of Technology and recently published by MIT Technology Press and John Wiley and Sons, Inc., deals in considerable depth with a major component of hydraulic control systems. Part I of the article was published in the April issue.

The book "Fluid Power Control" is a basic mathematical analysis of fluid power devices, with abundant design information on hydraulic and pneumatic systems and components. Copies of the book (priced at $17.50) may be ordered directly from Technology Press, Room 14 N-228, Massachusetts Institute of Technology, Cambridge, Mass. Descriptive literature detailing the book's twenty chapters may be had by writing No. 112 on the reader inquiry card.

11.24. Dynamic Analysis

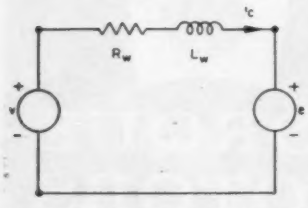

Fig. 11.33. Electric circuit of actuator.

Dynamic analysis of the devices can be simply generalized by means of linear theory, if operation of the nonlinear devices is restricted to the substantially linear range, and reduced to a single equivalent-circuit representation. For the electric-circuit equations, only the control current needs to be considered (except for the inclusion of polarizing current directly or indirectly in the expressions for certain parameters), though for computation of power losses, total current must be considered. For any of the devices,

$$v = R_w i_c + L_w \frac{di_c}{dt} + K_{1f} \frac{dx}{dt} \tag{11.49}$$

or

$$v = R_w i_c + L_w \frac{di_c}{dt} + K_{1t} \frac{d\theta}{dt} \tag{11.50}$$

in which v is the incremental terminal voltage, R_w is the winding resistance, and L_w is the winding self-inductance (armature centered). Either Eq. 11.49 or 11.50 describes the circuit of Fig. 11.33. Also,

$$K_{1f} i_c = M \frac{d^2x}{dt^2} + B_f \frac{dx}{dt} + K_{ef} x \tag{11.51}$$

or

$$K_{1t} i_c = J \frac{d^2\theta}{dt^2} + B_t \frac{d\theta}{dt} + K_{et} \theta \tag{11.52}$$

Here M represents the mass and J represents the moment of inertia of the moving parts, and B_f and B_t are viscous-friction coefficients. Use of

$$e = K_{1f} \frac{dx}{dt} \tag{11.53}$$

or

$$e = K_{1t} \frac{d\theta}{dt} \tag{11.54}$$

with Eq. 11.51 or 11.52, respectively, gives

$$i = \frac{M}{K_{1f}^2} \frac{de}{dt} + \frac{B_f}{K_{1f}^2} e + \frac{K_{ef}}{K_{1f}^2} \int e\, dt \tag{11.55}$$

or

$$i = \frac{J}{K_{1t}^2} \frac{de}{dt} + \frac{B_t}{K_{1t}^2} e + \frac{K_{et}}{K_{1t}^2} \int e\, dt \tag{11.56}$$

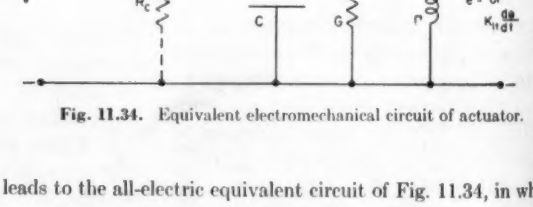

Fig. 11.34. Equivalent electromechanical circuit of actuator.

and leads to the all-electric equivalent circuit of Fig. 11.34, in which

$$C = \frac{M}{K_{1f}^2} \text{ or } \frac{J}{K_{1t}^2} \tag{11.57}$$

$$G = \frac{B_f}{K_{1f}^2} \text{ or } \frac{B_t}{K_{1t}^2} \tag{11.58}$$

$$\Gamma = \frac{K_{ef}}{K_{1f}^2} \text{ or } \frac{K_{et}}{K_{1t}^2} \tag{11.59}$$

The circuit may be made into a two-terminal pair by adding an impressed force, f_1, to the electromagnetic force, Eq. 11.51, and an impressed torque, τ_1, to the electromagnetic torque, Eq. 11.53, the equivalent of which is the impressed current, f_1/K_{1f} or τ_1/K_{1t}, whereas the equivalent of an impressed velocity is $K_{1f}(dx/dt)$ or $K_{1t}(d\theta/dt)$. Core losses may be represented approximately by resistance, R_c, Fig. 11.34, which is a function of frequency and flux density and can be estimated only roughly. It serves as an aid in visualizing the influence of core losses.

By Professor Richard H. Frazier
Associate Professor of Electrical Engineering
Massachusetts Institute of Technology

11.25. Figures of Merit

Figures of merit may be defined as aids in preliminary design procedure and in selection of motors. The ratio of starting force to mass or starting torque to inertia may be taken as a partial measure of speed of response. In computing these ratios, certain approximations are made for purposes of generality, since figures of merit generally need signify only substantial differences among various devices; if selection is very critical, accurate computation must be made for the specific devices or in specific design comparisons. For the moving-coil devices, the mass of the movable part is determined largely by the necessity of having sufficient surface area to dissipate heat at a rate that will keep the coil insulation within its temperature limit. For the translational device,

$$M = \pi Dtl[\sigma\delta_w + (1 - \sigma)\delta_i] = \pi Dtl[\sigma(\delta_w - \delta_i) + \delta_i] \quad (11.60)$$

in which t is the thickness and l is the length of the coils, σ is the over-all space factor, δ_w is the density of the wire material, and δ_i is the density of the insulating material. Insulating material has about 10 per cent the density of copper and about 30 per cent the density of aluminum:

$$\delta_c = \sigma(\delta_w - \delta_i) + \delta_i \approx (0.9\sigma + 0.1)\delta_c \quad (11.61)$$

for copper, and

$$\delta_a = \sigma(\delta_w - \delta_i) + \delta_i \approx (0.7\sigma + 0.3)\delta_a \quad (11.62)$$

for aluminum, and

$$M \approx \pi Dtl\delta_c \quad (11.63)$$

The current limit in the coil is determined by

$$i_c^2 R_w = i_c^2 \frac{\rho\pi DN^2}{\sigma lt} = k\pi DlT \quad (11.64)$$

if the coil is operated with control current only, and by

$$(2i_c)^2 \frac{R_w}{2} = (2i_c)^2 \frac{\rho\pi DN^2}{2\sigma lt} = k\pi D \frac{l}{2} T \quad (11.65)$$

if the winding is operated push-pull and hence carries quiescent current. Here ρ is the resistivity of the wire material, k is the dissipation factor in power per unit coil-surface area per degree of temperature rise, and T is the temperature rise. The coil is supposed to be thin enough that the internal temperature does not differ greatly from the surface temperature. The current limit then is

$$i_c = \sqrt{(k\pi DlT)/R_w} = \frac{l}{N}\sqrt{(\sigma klT)/\rho} \quad (11.66)$$

or

$$i_c = \frac{1}{2}\sqrt{(k\pi DlT)/R_w} = \frac{l}{2N}\sqrt{(\sigma klT)/\rho} \quad (11.67)$$

Hence, for maximum allowable flux density $\mathfrak{B}_p = \mathfrak{B}_m$,

$$f = \pi\mathfrak{B}_m\sqrt{(\sigma kT)/\rho}\, Dl\sqrt{t} \quad (11.68)$$

or

$$f = \frac{\pi}{2}\mathfrak{B}_m\sqrt{(\sigma kT)/\rho}\, Dl\sqrt{t} \quad (11.69)$$

and

$$\frac{f}{M} = \frac{\mathfrak{B}_m}{\delta_c}\sqrt{(\sigma kT)/(\rho t)} \quad (11.70)$$

or

$$\frac{f}{M} = \frac{\mathfrak{B}_m}{2\delta_c}\sqrt{(\sigma kT)/(\rho t)} \quad (11.71)$$

For the rotational device,

$$\tau = \mathfrak{B}_m\sqrt{(\sigma kT)/\rho}\, hDl\sqrt{t} \quad (11.72)$$

or

$$\tau = \frac{\mathfrak{B}_m}{2}\sqrt{(\sigma kT)/\rho}\, hDl\sqrt{t} \quad (11.73)$$

and

$$J = \frac{\delta lD\delta_c}{2}\left(hD + \frac{D^2 + l^2}{3}\right) \quad (11.74)$$

$$\frac{\tau}{J} = \frac{2\mathfrak{B}_p\sqrt{(\sigma kT)/(\rho t)}}{\delta_c\left(D + \dfrac{D^2 + l^2}{3h}\right)} \quad (11.75)$$

or

$$\frac{\tau}{J} = \frac{\mathfrak{B}_p\sqrt{(\sigma kT)/(\rho t)}}{\delta_c\left(D + \dfrac{D^2 + l^2}{3h}\right)} \quad (11.76)$$

If the angular accelerations of Eqs. 11.75 and 11.76 are translated into linear accelerations at the coil side, for comparison with Eqs. 11.70 and 11.71, the equivalent force-to-mass ratios are

$$\left(\frac{f}{M}\right)_c = \frac{\mathfrak{B}_m D\sqrt{(\sigma kT)/(\rho t)}}{\delta_c\left(D + \dfrac{D^2 + l^2}{3h}\right)} \quad (11.77)$$

or

$$\left(\frac{f}{M}\right)_a = \frac{\mathfrak{B}_m D\sqrt{(\sigma kT)/(\rho t)}}{2\delta_c\left(D + \dfrac{D^2 + l^2}{3h}\right)} \quad (11.78)$$

Hence, the rotational device cannot have as high starting acceleration as the translational device and can approach the starting acceleration of the translational device only if its coil is relatively high, short, or thin. Whereas the maximum force or torque of moving-coil devices is limited by the practical flux-density limit of the magnetic material adjacent to the air gap in terms of polarizing flux, $\mathfrak{B}_m = \mathfrak{B}_p$, the moving-iron devices are so limited by the flux density of polarizing plus control flux, $\mathfrak{B}_m = \mathfrak{B}_p + \mathfrak{B}_c$, and for a given upper limit of total flux density, the maximum force is achieved when the polarizing and control components are equal, $\mathfrak{B}_m = 2\mathfrak{B}_p$. Hence for the device of Fig. 11.3 the maximum force achievable is

$$f = \frac{\mathfrak{B}_m^2 wg_0}{\mu_a} \quad (11.79)$$

and the minimum mass of the armature is

$$M = \frac{wal\delta}{2} \quad (11.80)$$

so that

$$\frac{f}{M} = \frac{2\mathfrak{B}_m^2 g_0}{\mu_a al\delta} \quad (11.81)$$

Likewise, for the device of Fig. 11.4,

$$\tau = \frac{\mathfrak{B}_m^2 wg_0 l}{2\mu_a} \quad (11.82)$$

$$J = \frac{wtl^3\delta}{12} \quad (11.83)$$

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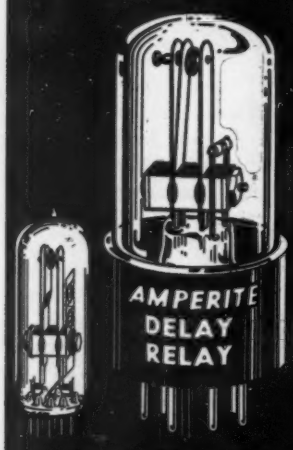

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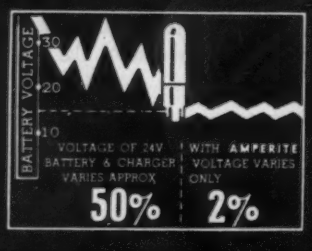

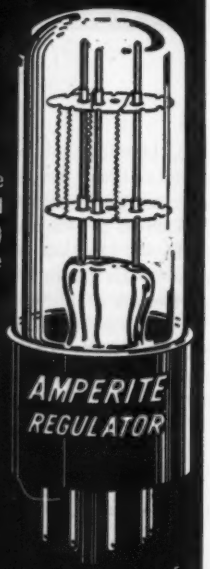

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CIRCLE NO. 19 ON INQUIRY CARD

This rotor must be twice as thick as necessary to carry the maximum flux because it must overlap each pole by $a/2$. It could be thinned in the center, but the decrease in J would not be great. Hence, somewhat pessimistically,

$$\frac{\tau}{J} = \frac{6\mathfrak{B}_m^2 g_0}{\mu_a a l^2 \delta} \tag{11.84}$$

$$\left(\frac{f}{M}\right)_e = \frac{3\mathfrak{B}_m^2 g_0}{\mu_a a l \delta} \tag{11.85}$$

for comparison with Eq. 11.76.

For the device of Fig. 11.5,

$$f = \frac{\mathfrak{B}_m^2 wa}{\mu_a} \tag{11.86}$$

$$M = wtl\delta \tag{11.87}$$

$$\frac{f}{M} = \frac{\mathfrak{B}_m^2 a}{\mu_a l t \delta} \tag{11.88}$$

and for the device of Fig. 11.6,

$$\tau = \frac{\mathfrak{B}_m^2 wa(l-a)}{2\mu_a} \tag{11.89}$$

$$\frac{\tau}{J} = \frac{6\mathfrak{B}_m^2 a(l-a)}{\mu_a l^3 t \delta} \tag{11.90}$$

$$\left(\frac{f}{M}\right)_e = \frac{3\mathfrak{B}_m^2 a(l-a)}{\mu_a l^2 t \delta} \tag{11.91}$$

For normal action, the rotational device has $\frac{3}{2}$ the starting acceleration of the translational device, and for parallel action, the rotational device has $3(l-a)/l$ as much starting acceleration as the translational device. For the two types of translational devices, the ratio of starting forces is

$$\frac{f_n}{f_p} = \frac{g_{0n}}{a_p} \tag{11.92}$$

which means that for equal forces the normal-acting device must be much the larger. The ratio of starting accelerations is

$$\frac{(f/M)_n}{(f/M)_p} = \frac{2g_{0n}}{a_p} \tag{11.93}$$

which reflects the same information. For the two types of rotational devices, the ratio of starting torques is

$$\frac{\tau_n}{\tau_p} = \frac{g_{0n} l_n}{a_p(l_p - a_p)} \tag{11.94}$$

which means that for equal torques the normal acting device must be much the larger. The ratio of starting accelerations is

$$\frac{(\tau/J)_n}{(\tau/J)_p} = \frac{g_{0n} l_p}{a_p(l_p - a_p)} \tag{11.95}$$

Actually, the comparison can be made still more favorable toward the parallel-acting device. The armature dimensions in all cases have been determined on the assumption that the flux densities in the armature cannot exceed the maximum flux density stipulated for the pole faces. However, if for the parallel-acting devices the armature cross-sectional area is reduced so that in the structure of Fig. 11.27, for example, the armature approaches saturation as it turns or so that in the structure of Fig. 11.24 the armature is always saturated by the polarizing flux, the nonlinearity is much reduced and the moment of inertia is reduced, without influencing starting torque. Furthermore, by saturating the armature, Fig. 11.24, it can be made solid and still have little hysteresis loss in it, which is a manufacturing advantage. If saturation is introduced into the normal-acting devices, they acquire negative K_τ and become nonlinear.

This effect can be visualized, for example, by consideration of Fig. 11.11 for balanced currents and displaced armature. The magnetomotive force across the air gaps on the end that has been pulled further into the stator then is less than the magnetomotive force across the

gaps on the other end; the armature tends to return to center, but the centering force is not in direct proportion to displacement, since it depends on the degree of saturation and hysteresis of the magnetic material.

Of the moving-iron devices, the parallel-acting device has the greater force and starting acceleration, and the rotational device exceeds the translational device in starting acceleration. A comparison of the parallel-acting rotating device with the moving-coil device in translation therefore is of interest. The ratio of forces is

$$\frac{f_c}{f_i} = \frac{\pi\mu_a\sqrt{(\sigma kT)/\rho}}{\mathfrak{B}_m} \times \frac{Dl_c\sqrt{l}}{w_i a_i} \tag{11.96}$$

if the moving coil does not carry quiescent currents, and is half the above ratio if the moving coil does carry quiescent currents. The ratio of starting accelerations is

$$\frac{(f/M)_c}{(f/M)_{ie}} = \frac{\mu_a\delta_i\sqrt{(\sigma kT)/\rho}}{3\delta_e\mathfrak{B}_m} \times \frac{l_i^2\sqrt{l}}{(l_i - a_i)a_i} \tag{11.97}$$

if the moving coil does not carry quiescent currents, and is half the above ratio if the moving coil does carry quiescent currents.

These ratios each have been factored into a part that depends on assumed limits for physical quantities and a part that depends on dimensions. Two comparisons now are made. First, for a copper winding,

$$\sigma \approx 0.50$$

$$k \approx 10 \text{ w/m}^2\,^\circ\text{C}$$

$$T \approx 200^\circ\text{C}$$

$$\rho \approx 3.0 \times 10^{-8} \text{ ohm-m at } 200^\circ\text{C}$$

$$\mu_a = 12.6 \times 10^{-7}$$

$$\mathfrak{B}_m = 1.5 \text{ webers m}^{-2}$$

$$\frac{\delta_i}{\delta_e} = 1.6$$

which gives

$$\frac{\pi\mu_a\sqrt{(\sigma kT)/\rho}}{\mathfrak{B}_m} = \frac{3.14 \times 12.6 \times 10^{-7}\sqrt{(0.50 \times 10 \times 200)/(3.0 \times 10^{-8})}}{1.5} \approx 0.48 \tag{11.98}$$

and

$$\frac{\mu_a\delta_i\sqrt{(\sigma kT)/\rho}}{3\delta_e\mathfrak{B}_m} = \frac{12.6 \times 10^{-7} \times 1.6\sqrt{(0.050 \times 10 \times 200)/(3.0 \times 10^{-8})}}{3 \times 1.5} = 0.084 \tag{11.99}$$

If the permissible temperature rise is reduced, or if the flux-density limit is raised, or both, the factors computed above are reduced.

Now for an edgewise strip-aluminum winding, using no bobbin or frame and relying on oxide insulation,

$$\sigma \approx 0.90$$

$$\rho \approx 5.0 \times 10^{-8} \text{ ohm-m at } 200^\circ\text{C}$$

$$\frac{\delta_i}{\delta_e} = 3.2$$

and if other quantities remain the same,

$$\frac{\pi\mu_a\sqrt{(\sigma kT)/\rho}}{\mathfrak{B}_m} = 0.50 \tag{11.100}$$

and

$$\frac{\mu_a\delta_i\sqrt{(\sigma kT)/\rho}}{3\delta_e\mathfrak{B}_m} = 0.17 \tag{11.101}$$

which shows little gain in force ratio but double the acceleration ratio.

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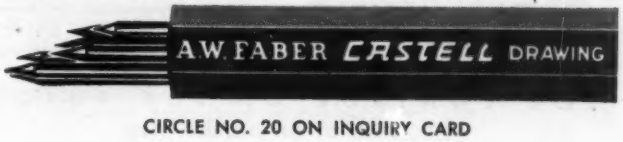

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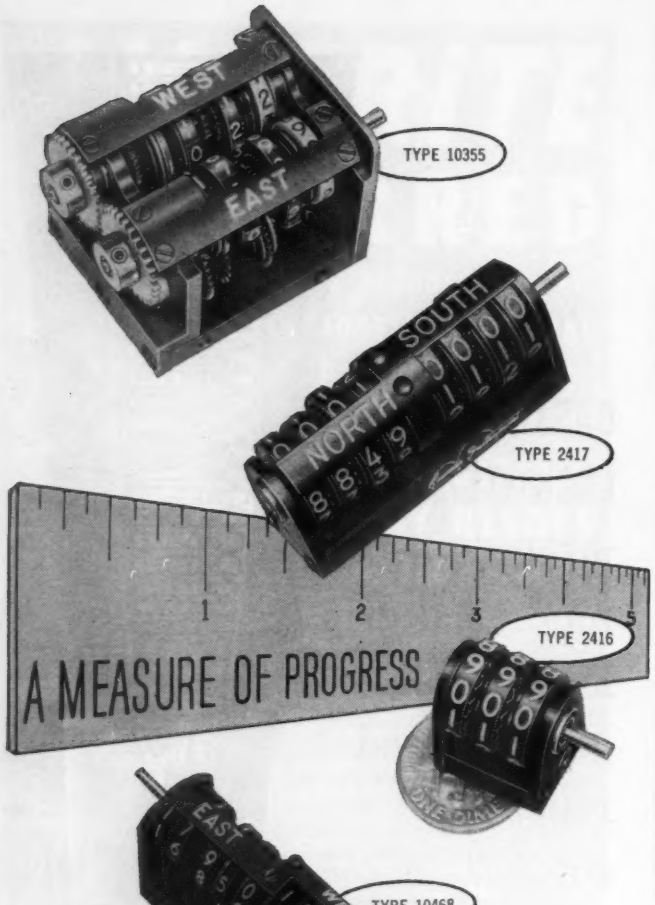

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To complete the comparison, some assumptions must be made for dimensions. For devices approximately the same size

$$\frac{Dl_c}{w_i a_i} \approx 1 \tag{11.102}$$

and generally

$$t \ll l_c \tag{11.103}$$

Therefore

$$\frac{Dl_c}{w_i a_i}\sqrt{t} \approx 10^{-1} \rightarrow 10^{-2} \tag{11.104}$$

for t between 10^{-2} and 10^{-3} m. Also, if

$$l_i \approx 4a_i \tag{11.105}$$

then

$$\frac{l_i^2\sqrt{t}}{(l_i - a_i)a_i} \approx 0.2 \rightarrow 2 \tag{11.106}$$

Evidently for comparable sizes, the moving-coil device is by far the weaker and has considerably smaller starting accelerations when sizes are small but could be superior in starting acceleration for large sizes. Specifications sometimes are made in terms of starting force, maximum stroke, minimum resonant frequency (with or without specified load), and control current. Specification of starting force and maximum stroke fixes effective elastance and, hence, fixes maximum mass or moment of inertia, which may fix too much. If the moving-coil translational device can develop the required force with a coil of a mass that is essentially the maximum tolerable, the moving-iron rotational device could develop the required force with an armature having much less than the tolerable moment of inertia, or in other words, could substantially exceed the specified resonant frequency. On the other hand, if the moving-iron rotational device can develop the required force with an armature having a moment of inertia that is essentially the required maximum, the moving-coil translational device could not develop the required force without using a coil of excessive mass.

$$\omega_0^2 = \frac{K_{ef}}{M} = \frac{K_{el}}{J} \tag{11.107}$$

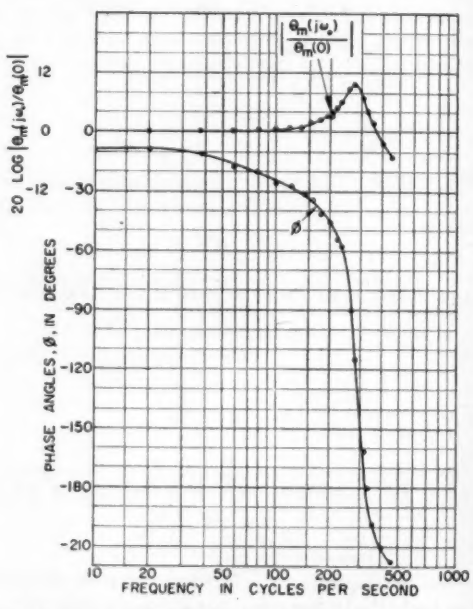

Fig. 11.35. Frequency-response characteristic of typical small torque motor.

Whereas resonant frequency may be taken as an indirect measure of speed of response, a better measure is phase lag. A frequency-response characteristic is plotted in Fig. 11.35.[3] For low frequencies, the phase

[3] R. H. Frazier and R. D. Atchley, "A Permanent-Magnet-Type Electric Actuator for Servovalves," Dynamic Analysis and Control Laboratory Report No. 66, Cambridge, Mass., June 1, 1952, Fig. 14, p. 23.

lag can be computed from

$$\tan \theta = -\frac{\omega(L_w + L)}{R} \tag{11.108}$$

in which

$$R = \frac{R_w R_c}{R_w + R_c} \tag{11.109}$$

in accordance with the equivalent circuit of Fig. 11.34. In fact, the entire frequency-response characteristic can be interpreted qualitatively from Fig. 11.34, but quantitative computation is not feasible beyond low frequencies owing to the complicating effects of hysteresis and eddy currents. The current in Γ is a measure of deflection and is not a maximum for the resonant frequency, for constant-signal-voltage excitation. For constant-current excitation, the phase lag with respect to *current* passes through 90°, and the deflection amplitude is a maximum at the resonant frequency except for the disturbing influence of core losses. Frequency response based on constant source current gives a characteristic of the device apart from influence of source impedance. Dynamic behavior, of course, could be expressed in terms of the roots of the determinantal equation for the circuit of Fig. 11.34 except for the effects of core losses. The natural frequency of the system, including voltage source and load, of course, is somewhat different from the resonant frequency.

As is evident by inspection of the equivalent circuit, Fig. 11.34, the speed of response is influenced not only by the mechanical parameters and the available force, or torque, but by the electrical parameters also, since the electrical time constant of the winding is a prime factor in determining the speed with which force can be developed. Hence, whereas for a given total flux-density limit, equal division of polarizing and control flux densities gives maximum possible force for a moving-iron device, reduction of control magnetomotive force by using larger polarizing and smaller control flux densities may be desirable to reduce winding inductances, control current, armature thickness, or coil heating. Division into 0.6 polarizing flux density and 0.4 control flux density gives 25 per cent reduction in control current (and perhaps in armature thickness), 36 per cent reduction in heating, and only 4 per cent reduction in force. For a given control magnetomotive force, reduction of turns reduces winding self-inductance and increases control current (or vice versa), but self-inductance is a squared function of turns, whereas control current is an inverse function of turns.

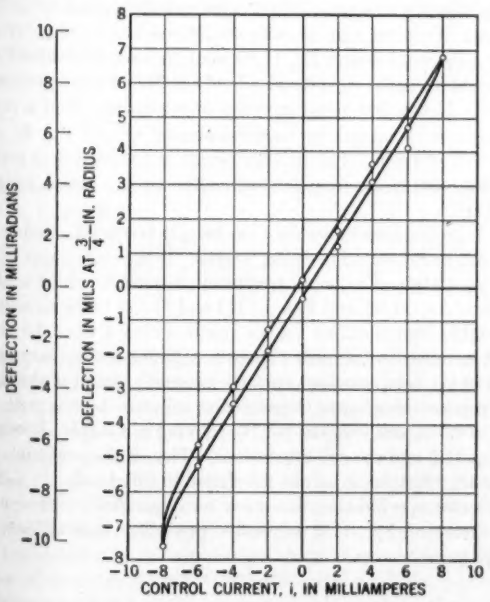

Fig. 11.36. Static characteristic of typical small torque motor.

The static sensitivity

$$\frac{\theta}{i} = \frac{K_1}{K_e} \tag{11.110}$$

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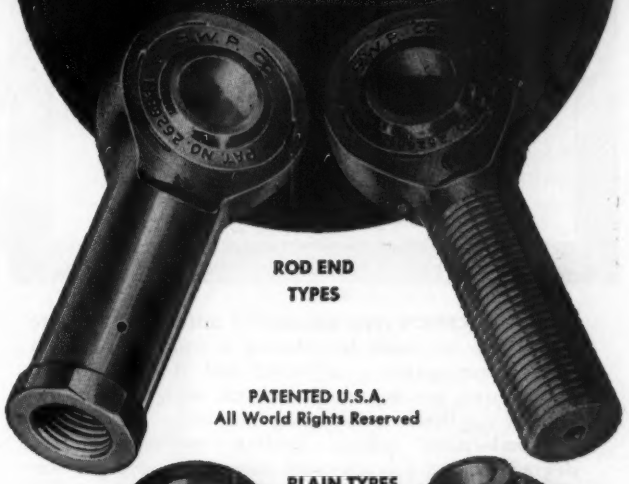

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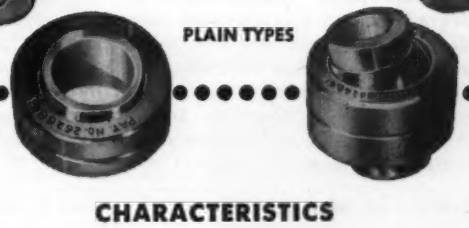

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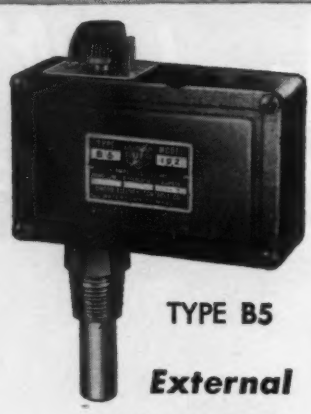

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(though θ/Ni is better as a characteristic of a given structure) is indicated by a static characteristic such as Fig. 11.36,[4] which gives an indication of linearity and of hysteresis, generally entirely of magnetic origin if centering springs are properly designed. To achieve very low hysteresis in moving-iron devices, one must select low-hysteresis materials with proper annealing, subject them to a minimum of machining or strain thereafter, and operate at low flux-density levels and with relatively long air gaps. These requirements tend to make large size and large control current necessary. Since pressure for small size and high sensitivity tends to dominate in actuator design, hysteresis is rarely less than 2 per cent of maximum stroke, though the situation might be improved somewhat by better attention to annealing and by methods of fabrication that avoid machining after annealing and strains produced by mounting. Hysteresis effects in moving-coil devices readily can be negligible, since the control current imposes only a relatively small magnetomotive force on magnetic material which is already polarized well towards saturation.

11.26. Design Procedure

Design procedure should be systematized to prevent running computations round and round without converging on a conclusion that meets the specifications or without realizing what items in the specifications are in conflict or are unreasonable and, hence, prevent a sensible solution. Since the achievement of ideal features in all respects inevitably involves conflicts in most design problems, the manner in which various requirements influence the design should be clearly evident so that compromises can be made in a way that best preserves the most desirable features for the application. Procedures can be systematized in various ways. For example, if starting force, maximum static deflection, resonant frequency, and current sensitivity are specified, a procedure for the moving-coil translational device, Fig. 11.1, is as follows.

Combination of Eqs. 11.63, 11.68, and 11.107 gives

$$\sqrt{l} = \frac{\mathcal{B}_m\sqrt{(\sigma kT)/\rho}}{\omega_0^2 d\delta_e} \tag{11.111}$$

in which d is the maximum static deflection. Use of Eqs. 11.63 and 11.107 gives

$$Dl = \frac{f}{\pi\omega_0^2 td\delta_e} \tag{11.112}$$

Hence, by assuming maximum air-gap flux density and quantities pertinent to winding design and heating which determine $\sqrt{(\sigma kT)/\rho}$ and δ_e, the coil thickness can be estimated from Eq. 11.111. (For a coil carrying quiescent current, Eq. 11.69 would be used instead of Eq. 11.68, which would halve the right-hand side of Eq. 11.111 and give t one-fourth as thick.) If the first result appears unreasonable, then a reasonable result must be achieved by modification of $\sqrt{(\sigma kT)/\rho}$, δ_e, specified ω_0^2, d, or all of them. The reasonableness of t is judged in part by the fact that it, plus clearances, determines the air-gap length across which $\mathcal{B}_m$ must act.

When a preliminary figure for t has been determined, combinations of D and l can be tabulated from Eq. 11.112. If the valve mass is included in the specification of resonant frequency, it must be added to the right-hand side of Eq. 11.63, and Eqs. 11.111 and 11.112 modified accordingly. If acceptable combinations do not result, either t must be revised or specified ω_0 must be changed. When acceptable preliminary figures for D, l, and t have been obtained, then the magnetic circuit of the device, including permanent magnet or polarizing coil, can be designed, and the number of turns and wire size for the moving coil can be determined by use of Eq. 11.5 and the coil dimensions. Then if the preliminary design still appears practical, it can be developed in full detail.

If the same specifications are used for a parallel-acting moving-iron rotational device, Fig. 11.6, a possible procedure is as follows. Use of Eq. 11.89 gives

$$fxr = \frac{4\mathcal{B}_m^2 z(1-z)wyr^2}{\mu_a} \tag{11.113}$$

in which

$$r' = xr \tag{11.114}$$

[4] Frazier and Atchley, *op. cit.*, Fig. 12, p. 23.

is the load radius (not to exceed $l/2$), and

$$a = yr \tag{11.115}$$

$$\mathcal{R}_e = z\mathcal{R}_m \tag{11.116}$$

$$\mathcal{R}_p = (1 - z)\mathcal{R}_m \tag{11.117}$$

The armature thickness becomes

$$t = 2yzr \tag{11.118}$$

Use of Eqs. 11.107 and 11.83 gives

$$fxr = \omega_0^2 J \frac{d}{xr} = \frac{2yzwr^3(2 + y)^3 \delta d\omega_0^2}{12x} \tag{11.119}$$

and combination with Eq. 11.113 gives

$$r = \frac{24\mathcal{R}_m^2(1 - z)x}{(2 + y)^3 \delta d\omega_0^2 \mu_a} \tag{11.120}$$

If the valve mass, M_v, is included in the specification of resonant frequency, and if the valve is split or counterbalanced, $2M_v(xr)^2$ must be added to the right-hand side of Eq. 11.83, and Eqs. 11.119 and 11.120 must be modified accordingly. Transposition of Eq. 11.113 gives

$$wyr = \frac{\mu_a fx}{4\mathcal{R}_m^2 z(1 - z)} \tag{11.121}$$

The last two equations, Eqs. 11.120 and 11.121, with Eq. 11.117 may be taken as the preliminary design equations. By assuming systematically combinations of x, y, and z, recognizing that practically

$$1 < x < 1.5 \tag{11.122}$$

$$0.3 < y < 1 \tag{11.123}$$

$$0.2 < z < 0.5 \tag{11.124}$$

the possibility of achieving reasonable dimensions can quickly be examined. If one starts, for example, with $x = 1$, $y = 0.5$, $z = 0.3$, preliminary values for r', r, w, a, and t are obtained which readily can be adjusted by proportion through juggle of x, y, and z. Whereas coil heating does not enter directly into these computations, as it does for the moving-coil device, it enters indirectly because r and a and the space needed for a shaft must be such that sufficient space is allowed for coils. The gap length will be of the order of three times the stroke unless a saturation effect is used to reduce nonlinearity. From this point, coil design (and magnet design, if permanent-magnet polarization is used) can proceed, using high-temperature insulation if necessary, and spring requirements can be investigated.

The electromagnetic elastance is

$$K_{2t} = \frac{(1 - z)fxr^2}{g_0 z} \tag{11.125}$$

(when all reluctance is concentrated in air gaps), and the required spring elastance is, therefore,

$$K_{0t} = K_{et} + K_{2t} = \frac{fx^2r^2}{d} + \frac{(1 - z)fxr^2}{g_0 z} = fxr^2\left[\frac{x}{d} + \frac{(1 - z)}{g_0 z}\right] \tag{11.126}$$

The spring torque for this type of device can conveniently be provided by the twist of its armature shaft. If a combination of x, y, and z cannot be found that gives acceptable r, w, a, and t, both from the point of view of over-all size and of practical coil and magnet design, specifications must be changed accordingly.

Procedures similar to the illustrations can be developed for any of the types of devices. The design of a motor using an E-I magnetic structure is given in Sec. 13.41. The type of device is often determined by mechanical adaptability to the application, shape of space available, or ease or expense of manufacture rather than by ideal analyses that optimize certain features. Furthermore, certain shapes, such as the cylindrical devices of Figs. 11.16, 11.22, and 11.23 and the magnetic circuits of the translational moving-coil device, are not readily laminated. The normal-acting moving-iron devices in translation may have high side forces owing to slight dissymmetries or unbalances, which may be quite troublesome if valves are rigidly attached to the armatures. Incidentally, any one

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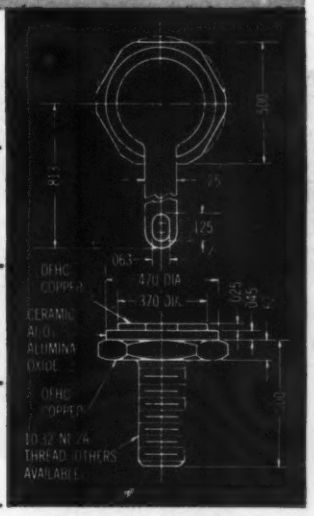

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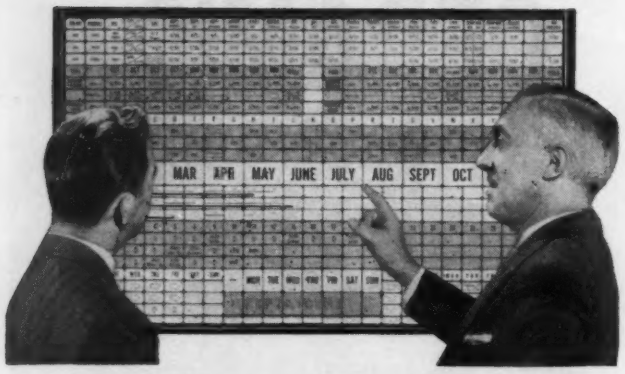

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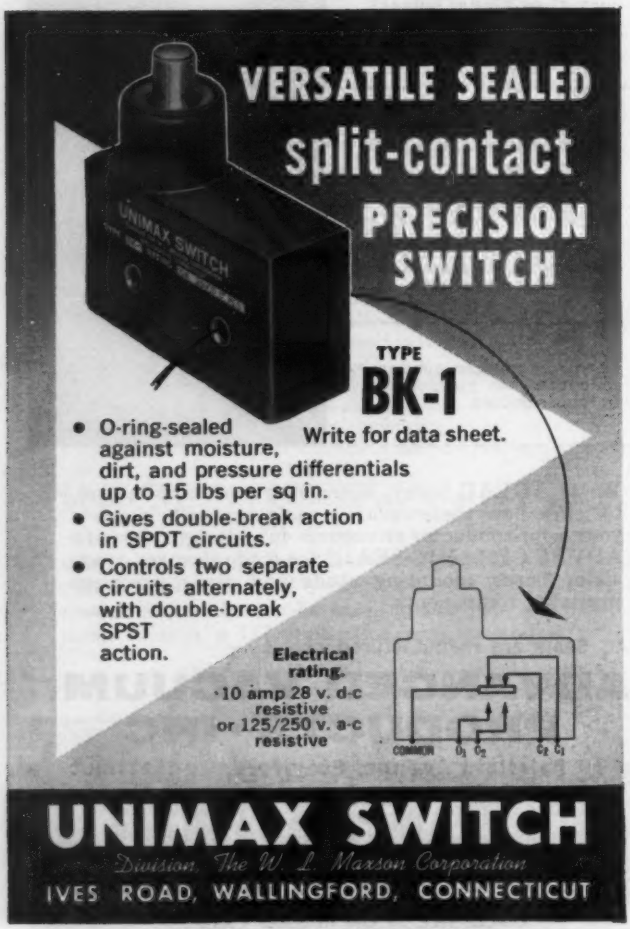

CIRCLE NO. 62 ON INQUIRY CARD

of the actuators illustrated herein can operate as a velocity pickoff. If the actuator is driven mechanically, it can generate a voltage proportional to velocity.

NOMENCLATURE

Symbol	*Definition*
a	polar length, radial direction
A	polar area at air gap
A_m	cross-sectional area of magnet
B	viscous-damping factor
$\mathfrak{B}_c$	control component of flux density
$\mathfrak{B}_m$	maximum allowable flux density
$\mathfrak{B}_n$	flux density at neutral section of magnet
$\mathfrak{B}_p$	polarizing component of flux density
C	capacitance
D	diameter
e	electromotive force
f	force
g_0	air-gap length, rotor in neutral position
G	conductance
h	height
$\mathfrak{H}_m$	magnetic-field intensity at neutral section of magnet
i_c	control component of current
I_0	polarizing component of current
J	moment of inertia
k	surface-heat-dissipation factor
K_0	mechanical elastance
K_1	electromechanical coupling constant
K_2	electromagnetic elastance
K_e	effective or net elastance
l	length
l_0	rotor overlap with stator pole
l_m	length of magnet
L_w	self-inductance of winding
M	mass
N	number of turns
$\mathcal{P}$	permeance
r	radius
R	resistance
R_e	core-loss resistance
R_w	resistance of winding
$\mathfrak{R}_0$	reluctance of working gap, rotor in neutral position
$\mathfrak{R}_n$	reluctance of nonworking gap
t	thickness
T	temperature
v	voltage
w	width
x	linear displacement
x	auxiliary design parameter
y	auxiliary design parameter
z	auxiliary design parameter
Γ	reciprocal inductance
δ	density
η	magnetic-leakage coefficient
θ	angular displacement
θ_0	g_0/r
μ_a	permeability of air
ρ	resistivity
σ	space factor of coil
τ	torque
ω_0	resonant angular frequency

ADDITIONAL REFERENCES

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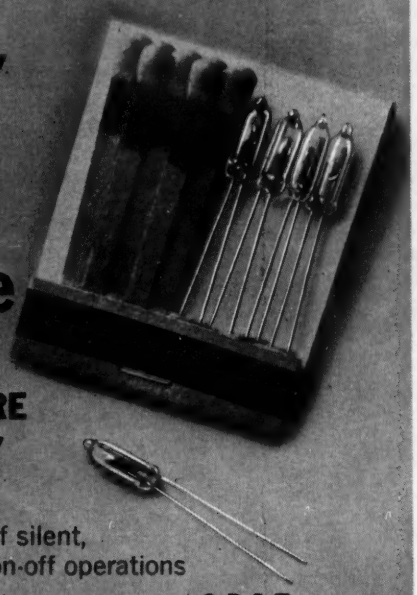
Dunn, J. F., Jr., "A Study of Permanent-Magnet Torque Motors," S.M. Thesis, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., 1953.

Frazier, R. H., and R. D. Atchley, "An Electric Valve Actuator for Hydraulic Servomechanism," Meteor Report No. 42, Dynamic Analysis and Control Laboratory, Massachusetts Institute of Technology, Cambridge, Mass., 1949.

Massachusetts Institute of Technology Electrical Engineering Staff, *Magnetic Circuits and Transformers*, John Wiley and Sons, New York, 1943.

1/2" long, .02 ounce



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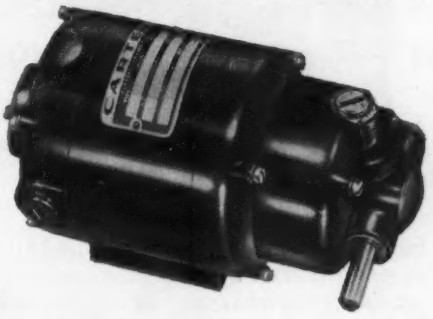

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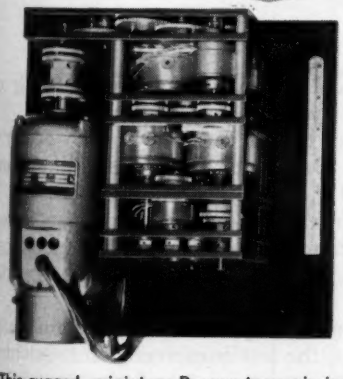

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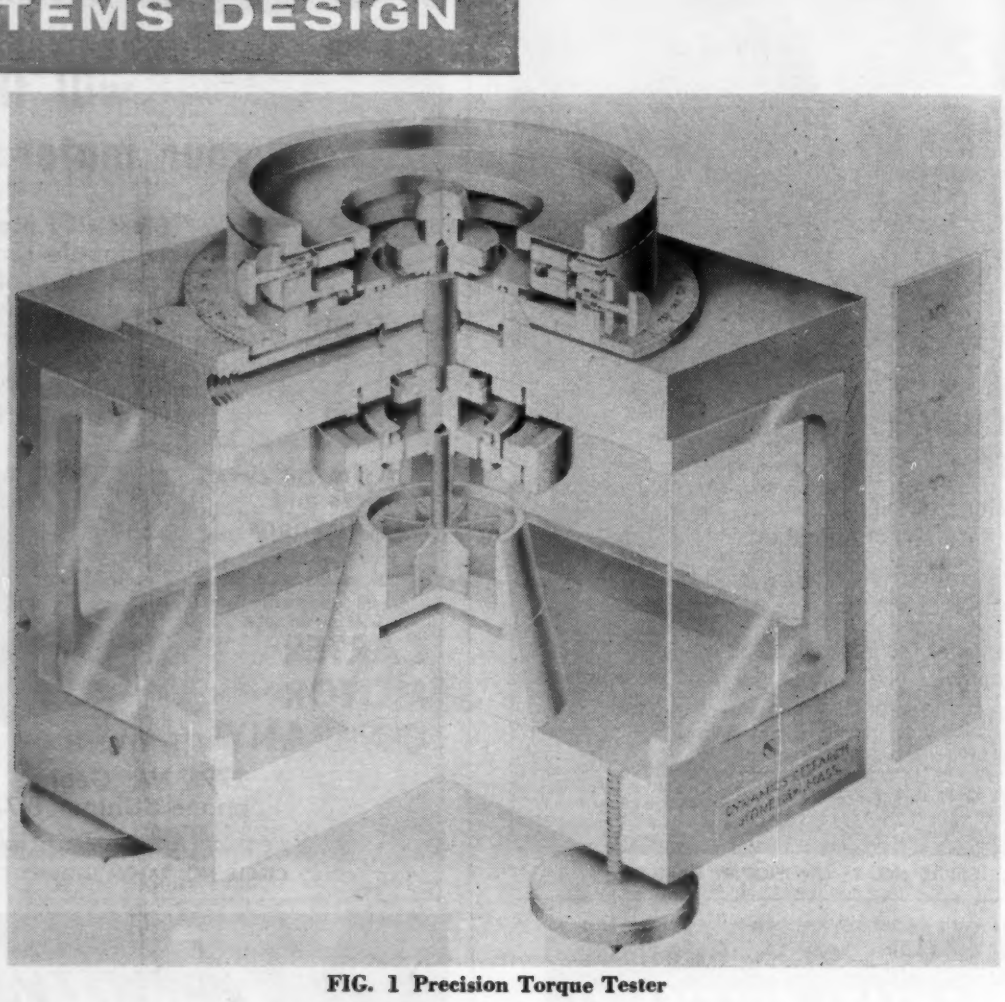

FIG. 1 Precision Torque Tester

PRECISION TORQUE TESTER

Air Bearing Design Maintains Stiff Axial and Radial Suspension

Development of a torque tester that measures torques well below the one-tenth dyne centimeter level has achieved the unusual result that, in one area at least, the art of the test equipment is slightly ahead of the art of the precision instruments tested. Key to this performance is the successful application of an air bearing to commercial torque measuring equipment.

In addition to its incredibly low friction, the bearing maintains an extremely stiff support in both the radial and axial direction for the device under test. The present test model, manufactured by the Dynamics Research Corporation of Stoneham, Massachusetts, will sustain a maximum test load of approximately one pound. Radial stiffness of the air support is of the order of 1.25 grams per micro inches, and its longitudinal stiffness is of the order of 1.0 gram per micro inch.

Air is supplied under pressure at forty to fifty pounds per square inch to the journal of the air bearing. When the bearing is activated, its residual friction is well below 10^{-3} dyne centimeters. Sources of error torque for the device are imperfections of the precisely machined surfaces and environmental disturbances. Performance results to date indicate the uncertainty torque of the air bearing is below 0.05 dyne centimeters for a moderately well controlled environment. DRC recommends controlling the inlet air pressure deviations to ± one pound per square inch and isolating the torque tester mechanical assembly from extreme air cu rents, temperature changes, and severe vibration.

The research model of the Air Bearing Torque Tester w developed by Robert DauWalter under the direction Phillip Gilinson at M.I.T. Instrumentation Laboratory. T purpose of the research was to devise a simpler, more acc rate method of determining the torque characteristics electromagnetic devices incorporated in high precisi gyros.

To measure very small torques in a device under pr cisely known conditions, the test equipment must orient a support the device with minimum interfering torque co tributed by the test equipment and the orientation of t device under test. In addition, the test equipment mu furnish a means for introducing the input conditions und which the torque is to be tested and a means for measuri the resulting torque accurately. For example, in testing t reaction torque of a Microsyn signal generator for a giv angle input, the Microsyn must be oriented and support so that the rotor is precisely centered with respect to t stator throughout the test, the rotational axis of the rotor vertical to prevent interfering torques due to mass unb ance of the rotor, and minimum friction torque interfer with axial rotation of the rotor. To supply the conditio under which the Microsyn reaction torque is to be measure some means of introducing a prescribed input angle betwe

the stator and rotor must be available; to measure this torque reaction some form of torque restraint of the rotor shaft and a means of sensing and indicating this restraining torque are needed.

Continuing our example of measuring the reaction torque of a Microsyn signal generator, we can show how the DRC torque tester fulfills the design requirements outlined. The Microsyn rotor is mounted on the air supported shaft of the tester so that the rotational axis of the rotor and shaft coincide and are vertical.

Spirit levels on precisely machined surfaces of the air bearing assembly indicate the orientation of the shaft with respect to the vertical and final alignment to the vertical is accomplished by leveling screws located at the bottom of the structure. Stiff axial and radial suspension maintained by the air support ensures that a new component of mass unbalance of the rotor is not introduced when the shaft is rotated.

Orientation of the stator with respect to the rotor is obtained by an adjustment fixture on the test table. Output signals developed by the Microsyn being tested are used as a basis for mechanically aligning the stator in the adjustment fixture to the electrical center of the combined stator and rotor. The alignment fixture provides two perpendicular axial motions with an adjustment resolution to within twenty millionths of an inch. It also provides means for adjusting the stator angle of the Microsyn being tested.

The block diagram in the accompanying figure illustrates the torque measuring system. Torque restraint is obtained by a closed loop spring. The loop includes a Microsyn signal generator (not the test specimen) and a microsyn torque generator attached to the air supported shaft.

The signal generator output voltage is proportional to the angular displacement of the air supported shaft. This output is amplified and fed back to the torque generator to produce a restraining torque on the shaft to balance the reaction torque to be measured. Damping of the restraint loop is provided by a paddle damper immersed in oil at the bottom of the air supported shaft.

A Weston Inductronic Product Resolver provides the

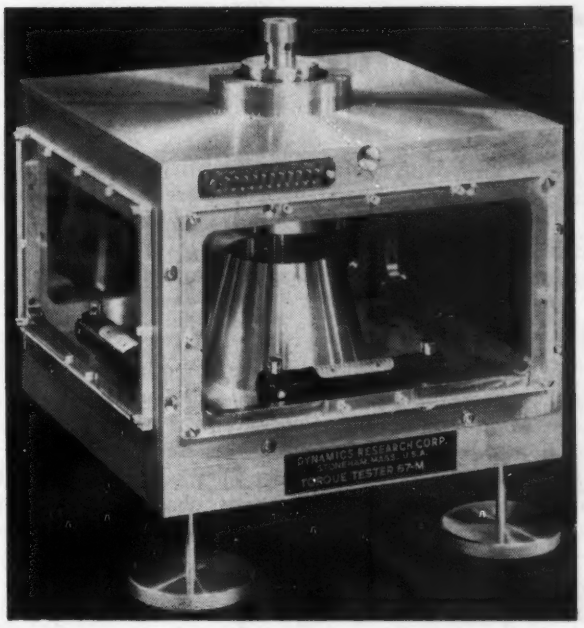

FIG. 2 Dynamic Research Corporation's Air Bearing Torque Tester

torque measurement. The Microsyn torque generator and Weston Inductronic primary windings are excited in series with the a-c reference source. The secondaries of the resolver and torquer are also in series. The current product output of the Inductronic is thus proportional to the torque generator output torque required to balance the reaction torque being measured.

Precision regulation of the a-c source is not required, since the Microsyns and reference winding of the Inductronic are excited from a common supply. Readout accuracy of the DRC torque tester is good to approximately 0.1%. The dummy director is used to calibrate any reaction torque characteristics of the restraint loop Mycrosyns. Maximum torque output of this design can be of the order of four to

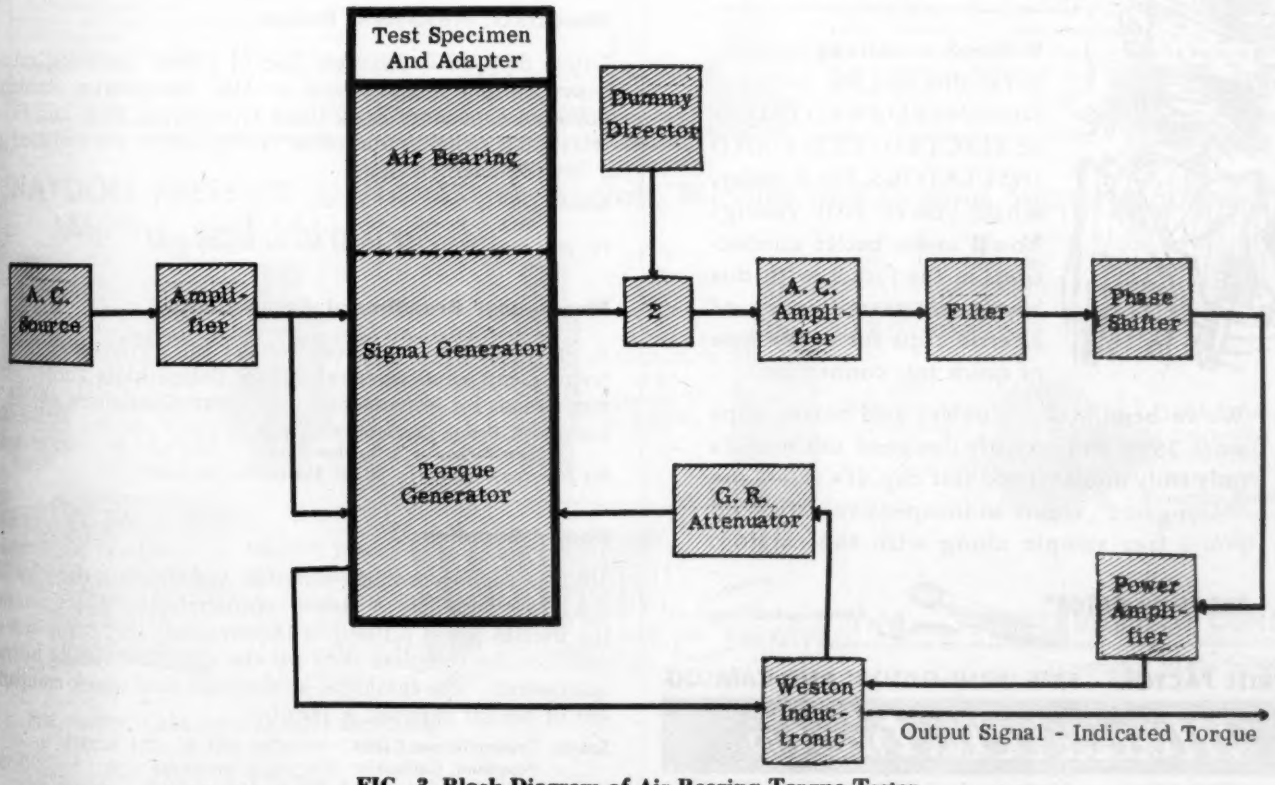

FIG. 3 Block Diagram of Air Bearing Torque Tester

five thousand dyne centimeters. In Microsyn testing, however, the normal torque range encountered is from one tenth of a dyne centimeter to one hundred dyne centimeters. If earth rate torquers for sizeable gyros were calibrated, the maximum torque required would be appreciably larger.

APPLICATIONS

The primary application for early models of the torque tester will be in determining the reaction torque of precision Microsyn pickoffs. Calibration of Microsyn torquers will be the secondary application. As a research device, the DRC Model 67-M2 offers potential for many new investigations. Static as well as dynamic characteristics of precision ball bearings can be examined to a low torque level.

Research may indicate that wheel assemblies of precise gyros can be checked for torque characteristics during the starting and coast-down intervals, either prior to, or after assembly into the hermetically sealed float assembly. Even after insertion of the gyro float in its outer case, wheel characteristics might still be checked. Thus the air bearing torque tester may provide a means of examining the torque characteristics of gyro wheels without disassembly of the unit. For example, after a precision gyro has operated for many hours, friction might increase due to lubrication evaporation, thereby altering the dimensional and preload characteristics of the gyro. Also, heating could have affected the gaseous medium in which the wheel spins. Examining coast-down torque characteristics might shed light on the nature of the wheel characteristics for correlation with unusual performance of the gyro.

The torque tester is actually in a dynamometer and thus can be used in calibrating and testing motors of all types. Its advantages, such as isolation from cross torques and forces, suggests its use in calibrating and testing other torque measuring devices.

It can be applied, in many types of instruments, to measurements of viscous shear, spring constant, hysteresis and acceleration characteristics in terms of instantaneous indications or as continuous plots as function of time.

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A new, compact technical booklet on mechanical breadboard components offers numerous design hints and recommendations for instrument engineers and designers.

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Power Supplies

16-page catalog contains complete specification data for d-c power supplies. A power supply selection chart permits the user to select his output requirements and turn, in seconds, to the complete data for the unit that fulfills his requirements. The catalog is so designed that quick comparison of similar supplies is possible.

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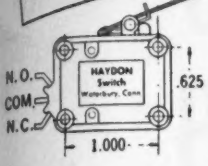
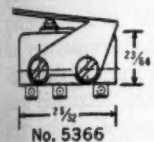


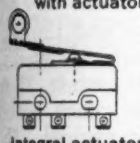
SERIES 5200 PLASTIC SNAP-ACTION SWITCHES

19 Models available with button in center position (5219), or with button in off-center position (5222) as shown at left with integral actuator. Terminals: Solder hold or taper tab feature. Meets snap-action switch specification MIL-S-6743 and vibration requirements of MIL-E-5272A, Procedure II.

SPECIFICATIONS TABLE	5219	5222
Contact Gap, min.	.030	010
Operating Force	6-10 oz.	20-27 grams
Release Force, min.	3 oz.	12 grams
Differential Travel, max.	.015	.030
Pretravel	.031	040
Overtravel, min.	.025	.050
Electrical Ratings, 30 Volts DC, 115 Volts AC	10 amps. Resistive 5 amps. Inductive	5 amps. Resistive 3 amps. Inductive
Ambient Temperature Range	−65° +300°F	−65° +300°F



No. 5366 with actuator



Integral actuator

SERIES 5300 SUBMINIATURE SNAP-ACTION SWITCHES

The basic 5300 switch meets the requirements of MS 25085, is available with a full range of operating forces from 2 to 20 ounces, and the case is made of Diallyl Phthalate. Versions with special characteristics and with integral roller and leaf actuators are available. Catalog information describes auxiliary actuators.

SPECIFICATIONS TABLE	5366	53114
Operating Force, max.	5 oz	20 oz.
Release Force, min.	1 oz.	4 oz
Differential Travel, max.	.004	.004
Overtravel, min.	.005	.005
Electrical Ratings, 30 Volts DC, 115 Volts AC	10 amps, Resistive 8 amps, Inductive	10 amps, Resistive 8 amps, Inductive
Ambient Temperature Range	−65° +300°F	−65° +300°F

7102

HAYDON HERMETICALLY SEALED SWITCHES

8102

6107

The standard, one piece heavy duty beryllium copper switch blade with fine silver contacts maintains contact without chatter, during shock and vibration, as required in military specifications such as MIL-E-5272. At Haydon Switch, a complete custom built design and development service is available to solve your problems in hermetically sealed switches and suitable actuators.

SPECIFICATIONS TABLE		6107	7102	8102
Contact Gap	IN.	.015	.020	.030
Operating Force, Max.	OZ.	22	32	64
Release Force, Min.	OZ.	6	6	8
Differential Travel	IN.	.0005-.005	.001-.006	.003-.015
Overtravel, Min. Available (In Use Do Not Exceed)	IN.	.007	.005	.010
28 Volts DC, 110 Volts AC (Amps Resistive)		5	10	25
28 Volts DC, 110 Volts AC (Amps Inductive)		3	4	8
Life at Rated Load (Actuations)		100,000	100,000	100,000
Ambient Temperature Range	°F	−65 +300	−65 +300	−65 +300
Altitude	FT.	0-80,000	0-80,000	0-80,000

TOGGLE-ACTUATED AND PUSHBUTTON SWITCHES

Several hundred variations of the toggle-actuated switches, using Haydon 5300 Series Snap-Action Switches, are available with from 1 to 8 pole double-throw contact arrangements. Toggle actuation can be either 2 or 3 position, and furnished in various combinations of momentary and maintained positions. Pushbutton switches available in 2-6 pole double-throw circuitry; many models feature positive acting or alternate action operating mechanism. Both types may be had with standard or panel seal bushings, and terminals may be solder hole, turret, or double turret.

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1890 Subminiature Absolute (2½ oz., 2¼" × 0.875")

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FOR TOGGLE AND PUSH-BUTTON SWITCHES CIRCLE NO. 35 ON INQUIRY CARD

MAGNETIC RECORDER FOR MISSILE TEST

Tape Drive Uses Photoelectric Transducers In Speed And Tension Control

Tape damage can be an exceedingly expensive event in missile data recording. To combat such damage, Ampex Corp., Redwood City, Cal., uses air to guide the tape in their new FR-600 analog recorder, selected as the primary recorder/reproducer of a telemetry ground station for testing Boeing's Minuteman missile. Although the recorder can handle up to 14 tracks of information over a frequency range of 300 cycles to 250 kilocycles per second, Boeing chose a 7-track configuration using ½ inch wide Mylar tape. Standard reels, 14 inches in diameter, provide 24 minutes of recording time at 60 inches per second recording speed.

Design goal for this application was 750 hours of recording time without failure, where failure was defined as any departure from specified performance during the life of the recorder. Fulfilling this requirement demanded utmost realiability in the tape drive.

TAPE DRIVE SYSTEM

The tape drive system on the FR-600 is an optimized close-loop drive system consisting of a capstan, turnaround idler, and pinchrollers. The capstan and turnaround idler are both slightly less than 2 inches in diameter. They are machined from aluminum and their surfaces are "Sanfordized" with aluminum oxide. Sanfordizing results in a surface hardened to the point that few elements other than a diamond can mar its finish. The capstan bearing assembly consists of suitably-loaded ball bearings supporting a capstan shaft tapered at both ends. The front taper carries the capstan surface proper and the rear taper carries a capstan pulley (flywheel). This flywheel incorporates a photoelectric tachometer to provide the control circuitry with the necessary information on capstan velocity. The turnaround idler also incorporates a photoelectric tachometer which senses the tape speed and relays this to the control circuitry. With a tachometer on the capstan flywheel and on the turnaround idler, action of the pinch rollers, which press the tape against the capstan, can be delayed until tape movement is up to proper speed.

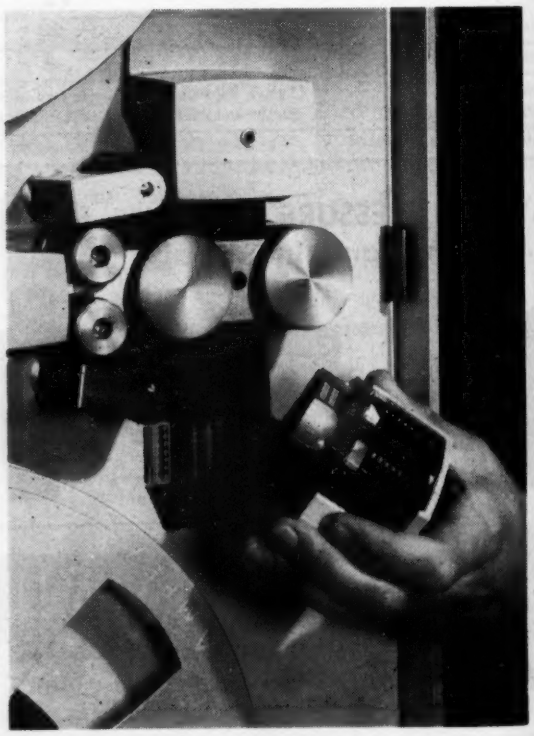
The tachometers on the capstan flywheel and on the turnaround idler consist of many grooves on the individual component which, when rotated, allow modulation of the light passing through to a photocell. These modulated light signals are fed to the control circuitry and compared by means of a summing circuit. Thus, when the frequency of the turnaround is up to that of the capstan, the pinch rollers are actuated and tape speed is then controlled by the capstan speed.

Both the pinch rollers and the capstan assembly are precisely mounted to the main frame transport casting. Thus, parallelism between the pinch rollers and the capstan can be assured. The pinch rollers are actuated by an air

Essential tape drive components of the Ampex FR-600 are shown at right. System consists of a capstan, turnaround idler, pinchrollers, tape guides, and magnetic record and reproduce heads. Capstan is large, perfectly-round component on left above. Turnaround is identical-looking component to right of capstan. Pinchrollers can be seen in position to clamp tape to the capstan. Record head is concealed by head-cover; reproduce head is being plugged in by operator. Tape guides are small, cylindrical-shaped components shown left of the capstan.

Tape is driven past the heads by a "closed-loop" drive arrangement wherein the pinchrollers clamp the tape against the rotating capstan both as the tape enters and leaves the magnetic head area. Tape is turned around the turnaround idler, and the record and reproduce heads are located between the capstan and turnaround. The record head is on the upper side of the closed loop, the reproduce head on the lower side. During record operations the upper pinchroller has the tape clamped against the upper portion of the capstan. During reproduce operations, the lower pinchroller moves into position to hold the tape securely against the lower part of the capstan.

The head assembly is electrically connected to the head cables as it is positioned on the head carriage. Each head assembly consists of a mounting plated with printed circuit connectors, head stacks (the exact number of stacks depending on the tape width, track arrangement, and type of head) and a cover. The entire unit is mounted on the tape transport by a single Allen head screw, which is accessible through a hole in the cover (this can be seen in center of record-head cover).



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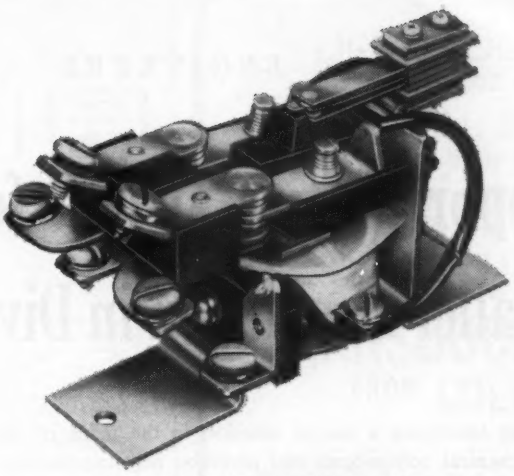
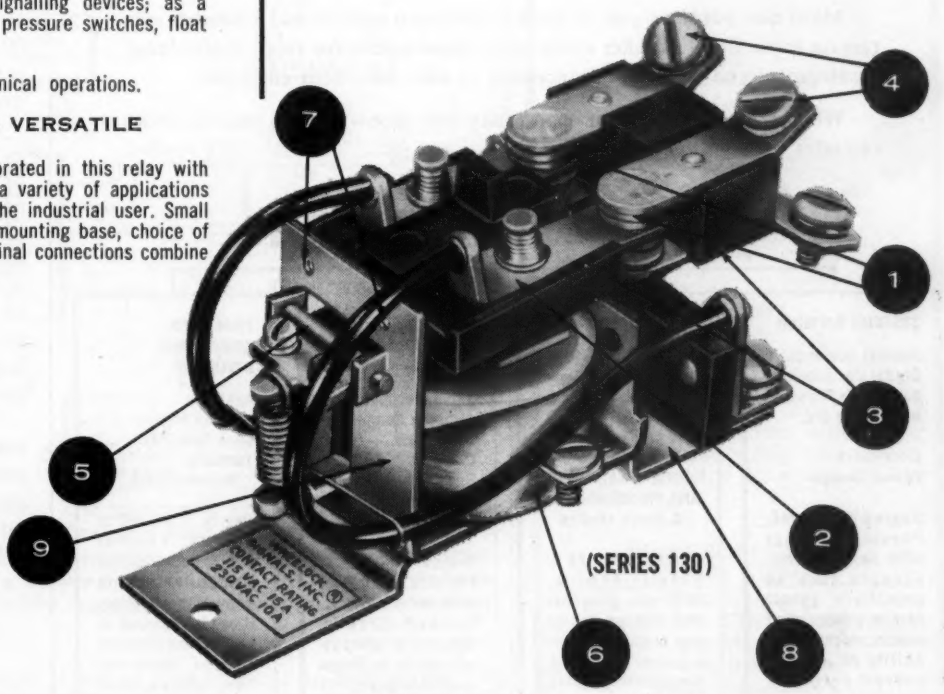
Special design details have been incorporated in this relay with the aim of making it readily adaptable to a variety of applications for both the equipment manufacturer and the industrial user. Small size and compactness, long life, choice of mounting base, choice of coil voltages (AC or DC), and choice of terminal connections combine to make the relay truly versatile.



AUXILIARY CONTACTS

(SERIES 131-141)

Auxiliary contacts (SPDT) rated 5 amps at 110 volts can be furnished with relay or easily attached later if required (see No. 7 below).



(SERIES 130)

1. **CONTACTS:** High capacity; generous safety factor; will handle 20 amps, 115 volt 60 cycle AC or 24 volt DC. UL approved for 15 amps, 116 volt 60 cycle, 10 amps, 230 volt 60 cycle.
2. **CONTACT ARMS:** Rigid arms backed by compression springs provide self-cleaning contact wipe.
3. **CONTACT SUPPORTS:** Moulded Bakelite supports provide high dielectric protection for both movable and stationary contacts.
4. **TERMINALS:** Large binding-head screws accommodate #12 wire or lugs.
5. **HINGE PIN:** Stainless steel ground to close tolerance assures contact alignment and long life.
6. **COILS:** Interchangeable; replaced by removing one screw in base: continuous duty.
7. **AUXILIARY CONTACTS:** (See illustration above).
8. **MOUNTING BASE:** Metal strap shown is standard. Mounting options shown on reverse side available at no extra charge.
9. **FINISH:** Cadmium Cronak.

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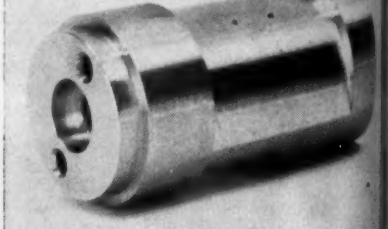
cylinder. This use of the air cylinde allows for a much greater pinch rolle travel and improves pinch roller mo tion. Since the air cylinder is spring loaded, as the pinch rollers approac the point of contact with the capsta a damping action takes place due t the loading on this spring inside th air cylinder. When the pinch roller are actuated, the actuation linkage ex ceeds its 90° point, thus the pinch rollers are held in place by the linkag and not by the air pressure behind th cylinder. Upon release of the air pres ure the spring inside the cylinder ha enough force to retract the rollers t their open position.

TAPE GUIDING

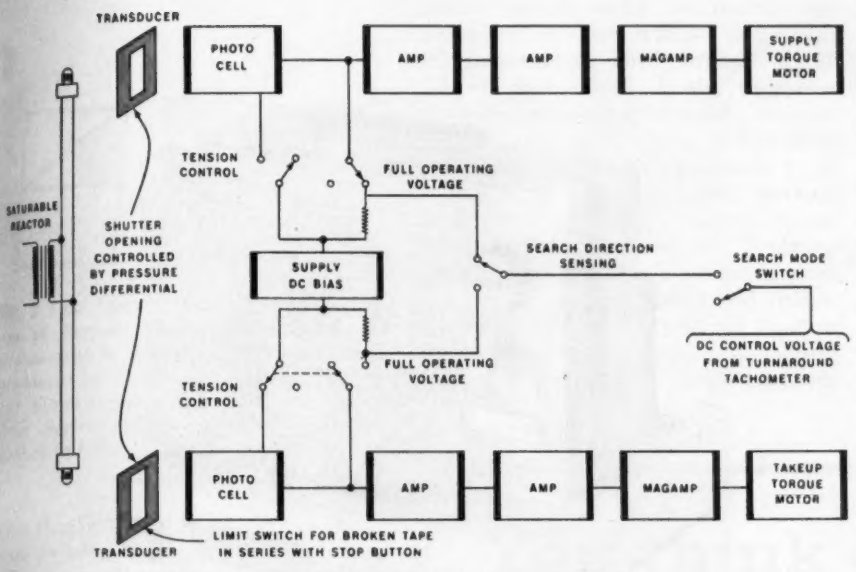
Tape guiding is accomplished by u of air-lubricated guides. The guidin consists of two lateral position guide one just before and one just after th pinch rollers, and two tensionin guides at the two reel positions. The guides are designed so that the ta is lifted from the surface of the gui by means of the air film. Also, by th manner in which the air lubricates th tape from the surface of the guid Ampex has found that air-leakage o both sides of the tape results in a sel centering action of the tape within th guide. The result is double-edge gui ing without the tape touching eith guide edge.

The air source is part of the pne matic system which consists of a com pressor, filtering equipment, air pres sure regulating equipment, and nece sary pumping and controls.

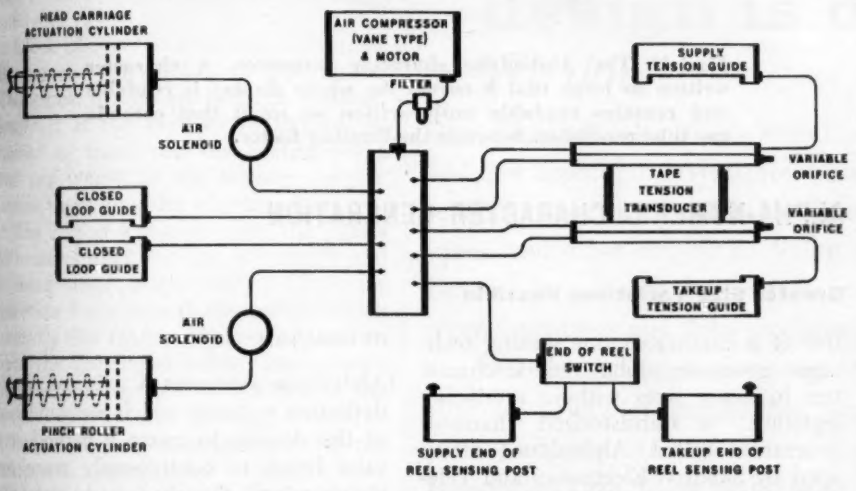
The two guides located just prior



Precision-machined tape guide. Ta guiding is accomplished by four a lubricated guides. These are fix guides. However, they can be manu rotated to accommodate either 1/2" o 1" wide tape. Photo shows machining top to accommodate 1" wide tape, a machining for 1/2" tape can be se on the underneath side of guide. Wh tape width is changed, the guides a pulled out, and rotated 180° to accom modate alternate width. All guides a interchangeable.



Block diagram of the air tensioning servo system.



Flow diagram of the pneumatic system. The pneumatic system is used for tape-guide lubrication, actuation of the pinchrollers and head carriages, to sense broken tape, and to sense the end-of-reel. System consists of a compressor, air pressure regulating equipment, a filter, and a blower for cooling of the transport capstan drive motor. Entire compressor assembly mounts in the lower left rear corner of the transport assembly.

the pinch rollers on the supply and takeup side of the capstan guide the tape in and out of the enclosed loop area. They perform only a guiding action. The other two guides are located at the extreme left of the tape transport surface, and are used for tension sensing as well as guiding. The upper guide controls the tension on the supply torque motor and the lower guide on the takeup torque motor (these are the motors for the supply and takeup reels of tape).

TAPE TENSIONING

Tape tensioning is accomplished by sensing the pressure behind the two tension guides. Ampex found that this pressure is a direct function of tape tension and when properly compared to a reference provides a direct indication of tape tension. In this system the pressure sensing is accomplished by use of a photoelectric transducer. Air pressure on one side of the diaphragm is controlled through a known orifice. Air pressure on the other side is that of the air leaking through the guide. When tape tension is increased, air flow through that guide is decreased, thus the pressure is increased moving the diaphragm in the photoelectric transducer. Movement of the diaphragm moves a piece of metal in front of a window and changes the light intensity passed to the photocell. Output of the photocell is fed to the control electronics, through two stages of amplification, a magnetic amplifier, and back to the torque motor which corrects the tape tension.

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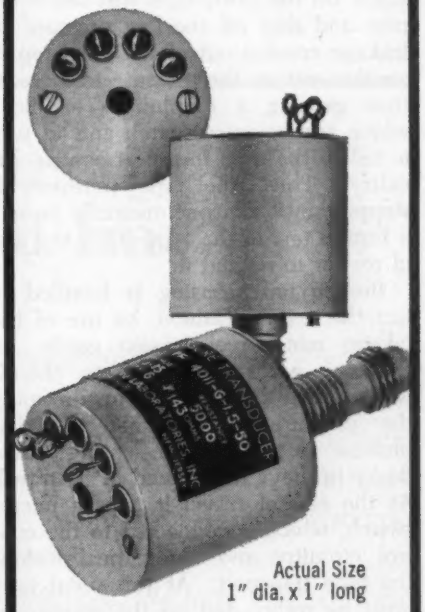

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END OF REEL SENSING

End-of-reel sensing is accomplished by use of two air posts, one between the supply reel and the supply reel guide, and the other between the takeup reel and the takeup reel guide. As one or the other of the reels approaches its empty position the attack angle from the guide to the reel changes. At a given point, which can be set by a turn screw on the post, tape will touch the post and shut off the low pressure air leakage coming out of it. This stop of air flow causes the pressure to increase thus causing a diaphragm to move which trips a microswitch and in turn is fed to the tape transport control circuitry. Thus, the tape transport is stopped until someone manually presses a button to run the tape off of the end of reel or to rewind it.

Broken tape sensing is handled in just the reverse fashion, by use of the takeup motor reel tension guide. In this case, when tape is broken, the air is allowed to leak freely, thus dropping the pressure and causing the diaphragm in the tension-sensing transducer to move to one end of its travel. At the end of travel it trips a microswitch, which is connected to the control circuitry and automatically stops the tape transport. At this point tape must be rethreaded on the equipment before any other load selection will function.

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Low Cost Ultrasonic Cleaner

A transistorized ultrasonic cleaner is said to be the first compact unit selling for less than $100. It will handle safely anything from tiny semiconductors to meters and clocks, and from miniature bearings to gyros, as well as other components of electronic and mechanical systems. Unlike tube-equipped ultrasonic models which consist of separate generator and cleaning tank units, the new transistorized cleaner is a self-contained unit. The base houses the generator and a recessed circular barium transducer upon which is placed a 400 milliliter beaker containing the cleaning solution. The transistorized circuit receives about 40 watts of d-c imput and produces about 30 watts of 65 kc output. It plugs into an ordinary 110-220 volt circuit, thus requiring no special power lines. Narda Ultrasonic Corp., Westbury, N.Y.

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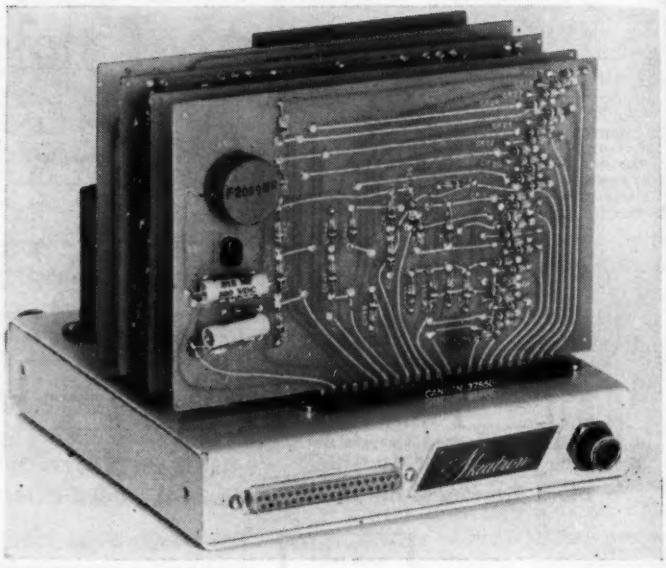

Fig. 1 The Alphadyne character generator. A character written so large that it covers the whole display is readable and remains readable until written so small that cathode ray tube resolution becomes the limiting factor.

ALPHA-NUMERIC CHARACTER GENERATION

Greater Size Variations Possible

Use of a continuous line writing technique generates alpha-numeric characters in many sizes without sacrificing legibility. A transistorized character generator, called Alphadyne, developed by Skiatron Electronics and Television Corp., New York City, New York, produces numbers, letters and symbols for display on any cathode ray tube. Combinations of strokes, which are part of a basic matrix, form the characters.

OPERATION

Alphadyne generates X axis and Y axis deflection voltages which are combined at the display to cause a cathode ray tube beam to continuously trace out the matrices. Simultaneously, intensification voltages (Z axis) illuminate those matrix strokes required to form the particular character desired. Input selection lines generate each character for as long as the logical voltage level

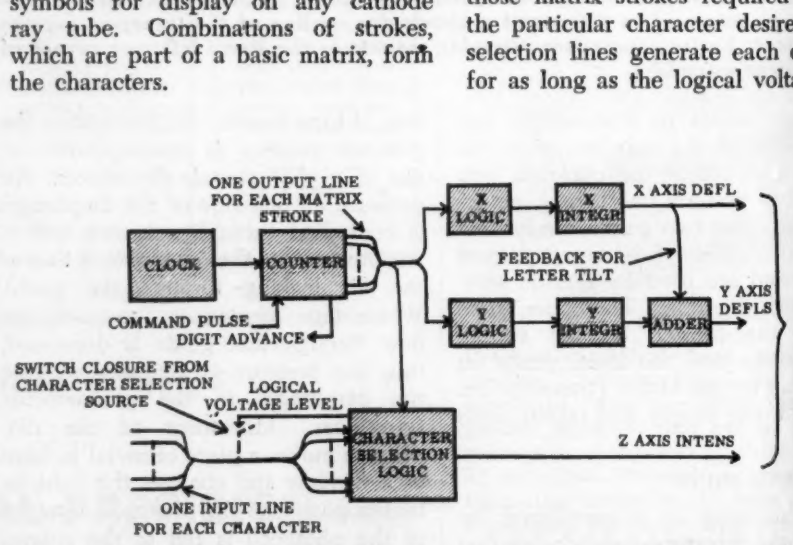

Fig. 3 Block diagram of the Alphadyne character generator. Because the deflection and intensification voltages are derived from the same clock, no registration problems are encountered. The digit advance output pulse allows the Alphadyne to control a character selection source, such as a computer. The command pulse allows the character writing to be synchronized from an external source.

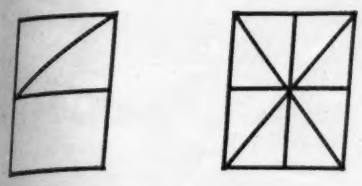

Fig. 2 (a) Any digit and some letters can be formed from combinations of strokes which are part of this matrix produced by Alphadyne Series 2000. (b) A more elaborate matrix of Alphadyne Series 3000 contains sufficient strokes to write all digits and letters.

(less than 15v d-c) is energized. Solid state switches, mechanical switches or relays can make connections between the character selection line and logic voltage.

Clock rate is the character rate times the number of strokes in the matrix. The clock drives an n stage counter, where n is the number of strokes required to trace out the matrix. One line per count, at the counter output, drives three parallel circuits.

The X and Y logics select the pulses to be combined and fed into the X and Y integrators, respectively. Character selection logic selects the pulses which intensify the matrix strokes required to form the particular letter. For a more pleasing appearance, a fraction of the X deflection voltage is coupled into the Y deflection output in order to tilt the characters slightly.

Alphadyne has no operating controls or alignment adjustment other than power and mode select switches. Use of transistors and solid state diodes through-out the unit achieves small size, low power consumption, and high reliability.

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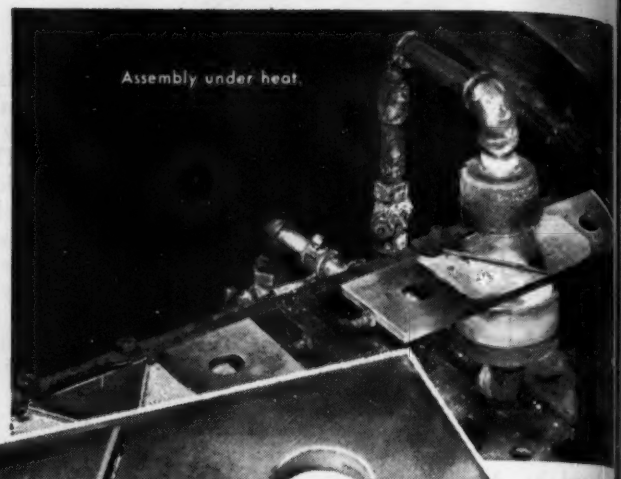
Three-part bus bar contact assembly; triangular piece, EASY-FLO shim and base plate.



Assembly under heat.

Note smooth, even fillet of completed assembly

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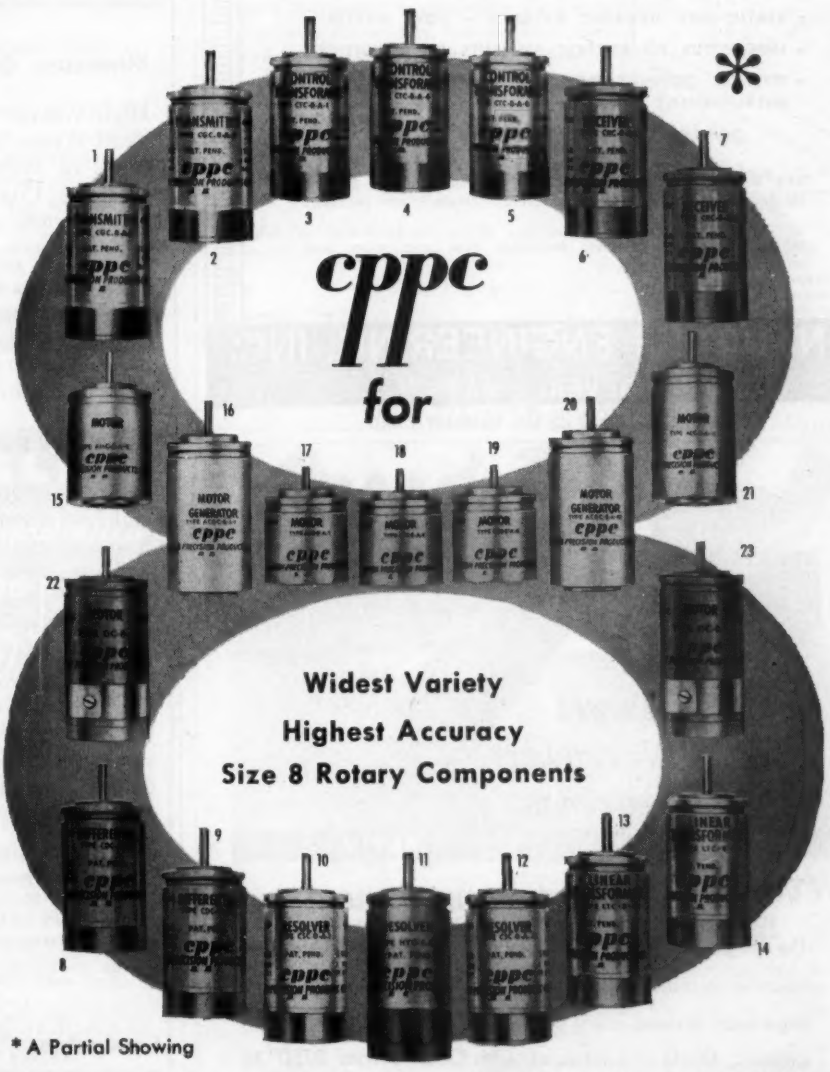

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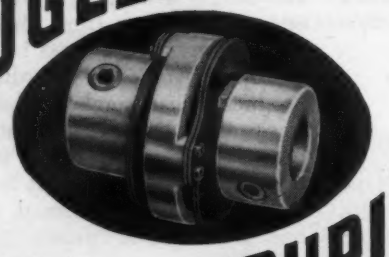

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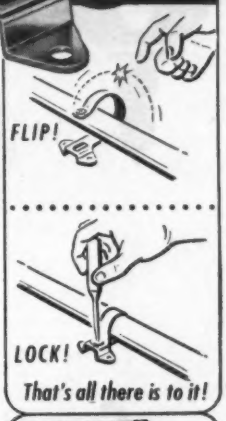

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ANALOG-DIGITAL CONVERTERS

EPSCO DATRAC Voltage to Digital Converter Model B
- Input ±10 V.
- Output 11 bit binary including sign High speed-approximately 45,000 conversions per second
- Accuracy ±.05% ±½ the least significant digit
- Reversible—digital input, analog output The Standard in the industry—see July issue Electromechanical Design

COLEMAN DIGITIZER— Shaft Position to Digital Converter Model A 4DT-S9
- Decimal Output 0-9,999
- 100 counts per shaft revolution
- Reliable—10 million revolutions at 500 RPM with a make-break load of 28 VDC at 250 MA.

LIMITED QUANTITY OF NEW EPSCO AND COLEMAN UNITS AVAILABLE AT GREAT SAVINGS. WRITE FOR FURTHER DETAILS AND PRICES.

ELECTRONIC ASSOCIATES	
VARIPLOTTER	MODEL 205J
One unused unit available	$4980

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Speed Tying Operations!

★ Cheaper than String
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Top view of Hanscom-Tie as shown. Bottom is flat

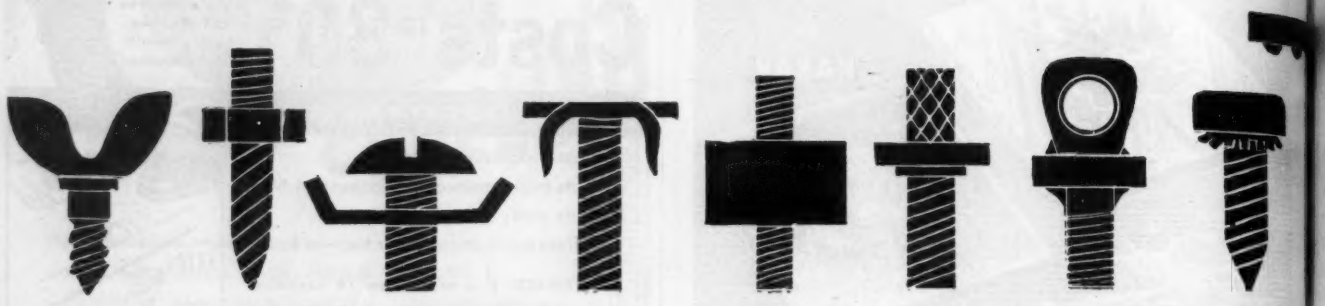
NO KNOTS TO TIE!

Cut your tying time in half! Hanscom-Ties are the fast, sure way to bundle wires, cords, coils, etc. Nothing to tie. Just wrap 'em around and twist. For temporary or semi-permanent holding. Available in cut lengths 1" to 24" and on spools — bright colors or printed. Prices from 26c per thousand. WRITE FOR SAMPLES and TRY 'EM YOURSELF.

Hanscom-Ties®

CIRCLE NO. 47 ON INQUIRY CARD

DESIGN TIME SAVER



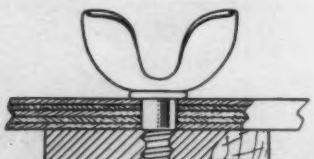
FASTENING DESIGN FO

Compared to other, more esoteric, problem areas of engineering activity, fastening problems and solutions appear mundane. But hardly any advance in new components or systems—whether for military, industrial or consumer application—takes place without a fair share of time spent on the design of new types of fasteners or the selection of available fasteners to solve joining problems. Indeed, the fastening problem in many cases may be a determining factor in new designs or configurations.

As a "design time saver" the editors of ELECTROMECHANICAL DESIGN print this "short form" handbook of fastener selection primarily based on material compiled by engineers at Central Screw Co. in Chicago, Illinois. To this as indicated in various categories, we have added selected fasteners from other companies to round out the organization of designs for speed, inserts, safety, simplicity, appearance, adjustment and sealing.

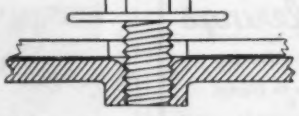
This collection is by no means complete, nor does it represent an industry wide survey on what is available from whom. Over 100 fastening methods can, however, function as a starting point toward the solution of your fastening problems. Most of these fasteners are available from local suppliers.

DESIGNS FOR SPEED



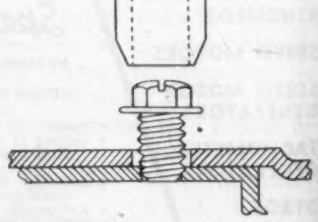
1. Combining wood screw threads to wings results in speed of adjustment when applying thumbscrews to wood.

2. Stamped wing nuts "spin on" in assemblies requiring long thread take-up; ideal for both speed and economy.

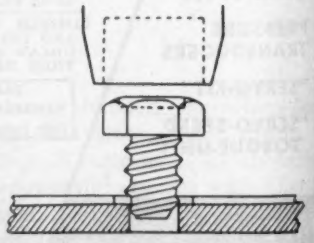


3. Speed and convenience are combined in the special indented hex-washer head. One piece washer design permits large area coverage and protects against wrench disfigurement.

4. Add speed to your production lines by using automatic air or electric drivers with Phillips recessed heads to protect enameled surfaces from driver slippage damage.



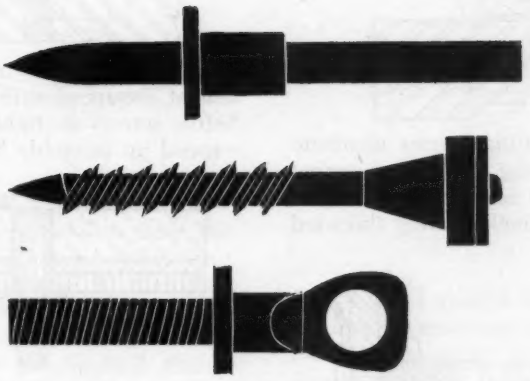
5. Acorn head design delivers both speed in assembly and protection for finished surfaces against wrench disfigurement.

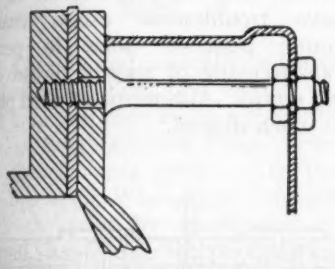


6. Hexagon head self tapping screws speed up the tempo of production lines when tapping through thicker sections with maximum applicable wrench torque.

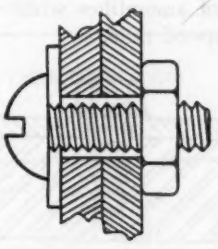
FOR

SPEED
INSERTS
SAFETY
SIMPLICITY
APPEARANCE
ADJUSTMENT
SEALING

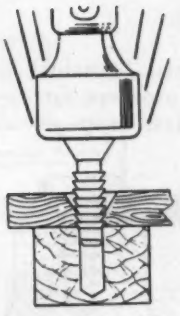




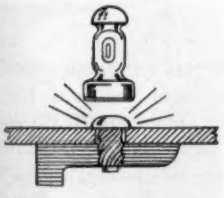
7. Reheaded fasteners provide a fast means of assembling spacers when provided with hexagon collars.



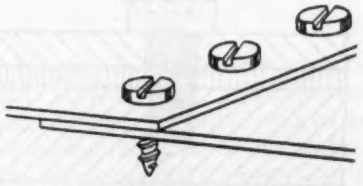
10. Double chamfered machine screw nuts can be assembled in automatic machines. Both sides are right sides to save "turn-over" labor dollars.



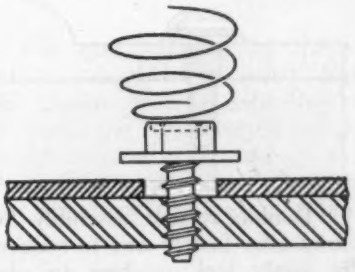
13. Special annular threaded members driven into place offer quick locked-in assembly methods.



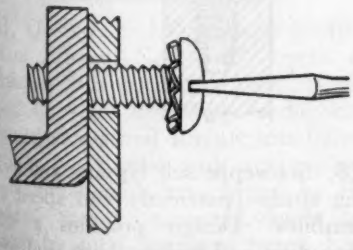
8. For fast hammer driving into wood, plastic or metal, drive screws offer real speed advantage. Covers, nameplates, metal to metal assemblies, metal to wood or wood to wood; permanent and tamper proof.



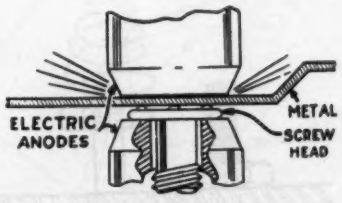
11. When assembling light gauge sheet metal, self tapping screws offer both speed and economy.



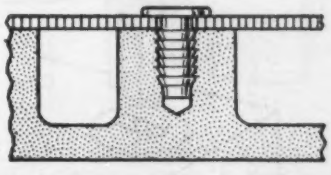
14. Plain washer Sems screws save time-provide added head surface required to fill up large clearance holes.



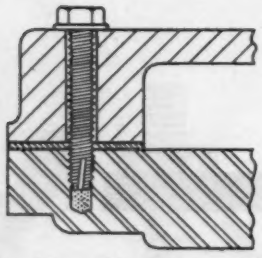
9. Production speed is greatly increased when pre-assembled Sems lock washer and screw are specified as one complete unit.



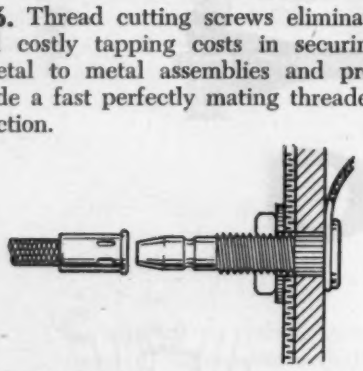
12. For fast attaching of threaded members to sheet stock, welding screws offer the most efficient design.



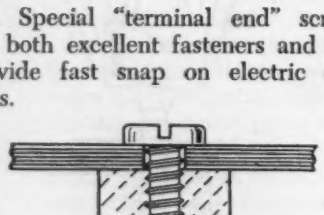
15. Special (annular threaded) drive pins speed up assembly time in attachments in plastics. Just drive them in like a nail.



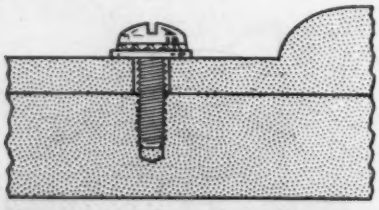
16. Thread cutting screws eliminate all costly tapping costs in securing metal to metal assemblies and provide a fast perfectly mating threaded section.



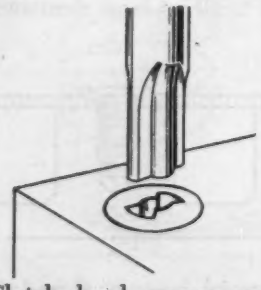
17. Special "terminal end" screws are both excellent fasteners and also provide fast snap on electric contacts.



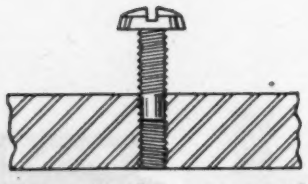
18. Thread cutting screws offer the fastest method of assemblies without fear of breakage.



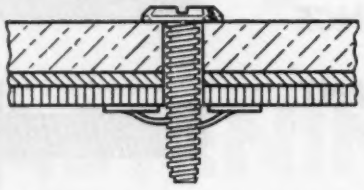
19. Double washer assembly Sems screws offer fastest way to economically apply lock washers to plastic material; large plain washers span slotted areas.



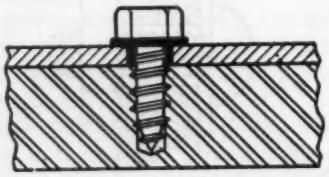
20. Clutch head screws speed up driving time—provide sturdy driving bits for application requiring high tightening torques.



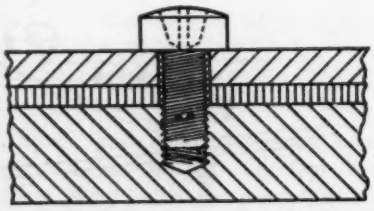
21. Dog pointed screws provide excellent means of safe pre-assembling before screws are tightened into place —speed up assembly line operations.



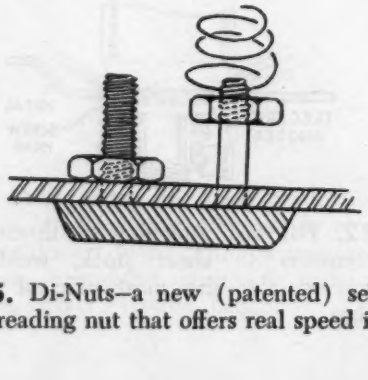
22. Special Acme threaded fasteners provide strong, fast and sturdy vibration-proof assemblies when used with proper speed nuts.



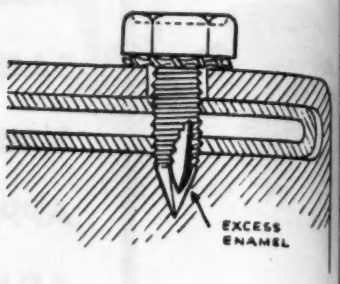
23. Special designed neoprene washers preassembled to plain or recessed underhead surfaces offer perfect, quick threaded sealant fasteners. Provide perfect seals against weathering or chemical acids.



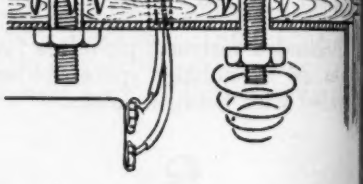
24. Thredlock (patented) fasteners provide an excellent, fast built-in locking feature for designs where prelocations are well determined insuring against failures from excessive vibrations.



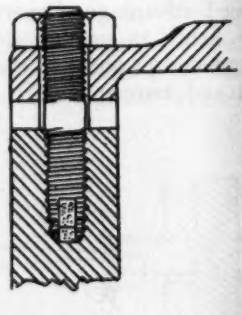
25. Di-Nuts—a new (patented) self threading nut that offers real speed in assemblies requiring a cast stem or unthreaded stud to be permanently assembled—vibration proof.



26. Special enamel reaming thread cutting screws offer appliance manufacturers a real answer to assembly problems. Here is a special threaded fastener especially designed to remove troublesome excess enamel around punched holes to permit crack-free use of speedy thread cutting screws. Also for paint filled pockets when dipped.



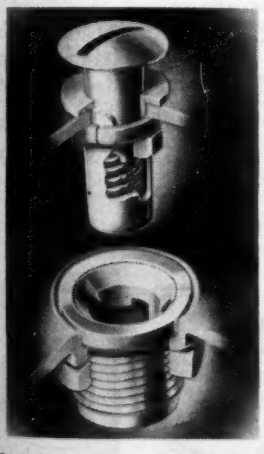
27. Special struck pronged heads offer the ideal solution for attaching threaded members to plywood, gra board, soft plastic and other pane fast—with the lowest overall assembly cost.



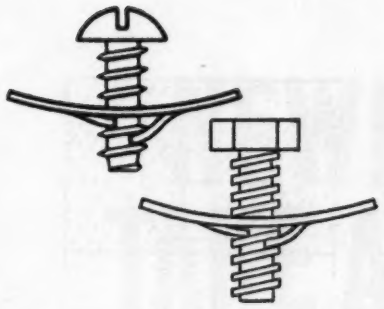
28. Schweppe self tapping and lo ing studs—(patented) can speed semblies. Design provides a threading and locking base stud w perfect mating internal threads, a bodied unthreaded shank, perf tightening member thread, and so many re-assembly field problems.

29. Keps nuts are internally threaded, self-locking, complete unit—one piece—one inventory; perfectly balanced engineering with speed in assembly and assurance for all maintenance problems.

30. Locking and unlocking is accomplished in fractions of a second with a ¼ turn fastener made by Southco Div. of South Chester Corp., Lester, Pa. Swaged nose gives lasting, positive operation. When locked, the joint is tightly sealed by compression of a rugged leaf type receptacle. Conforming to Mil-F-5591A (ASG), the fastener has high tensile and shear strength and a high strength-weight ratio.

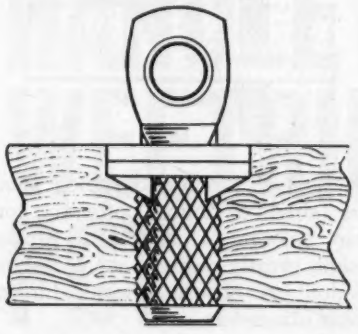


31. Quick-Lock by Simmons Fastener of Albany, New York, opens or closes with a 90 degree twist, is self ejecting when unlocked, works with curved sheets and slightly misaligned holed. No special tools are needed; only initial loads are carried by the helical spring; increased loads are taken by solid supports. Screw type receptacles accommodate wide range of material thicknesses through variance of depth of receptacle installation dimple.

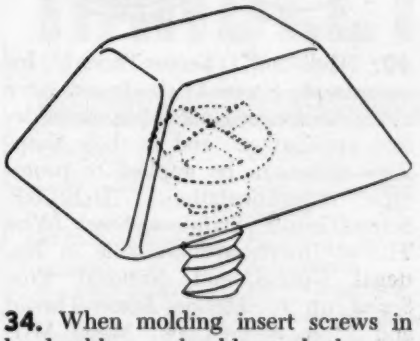


32. "Speed-Nuts" can be made in a variety of configurations to meet the needs of a specific design. All designs are similar in function in that they spin down easily, lock securely without extreme torques, accommodate wide variations in standard thread dimensions, and pound for pound of holding strength they weigh less than ordinary nuts.

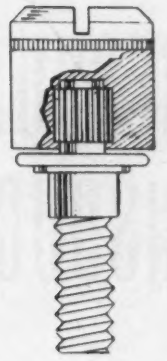
DESIGNS FOR INSERTS



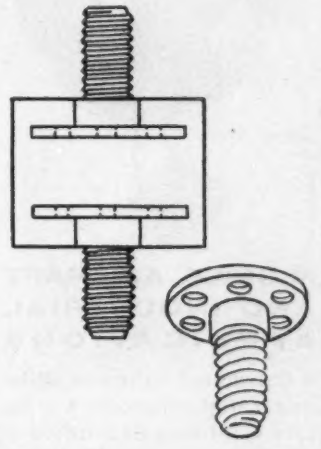
33. Inserts for thermoset plastics should provide both correctly designed shoulders or collar sections to resist outflow and proper antirotation means such as special diamond knurls, ribbed or finned shoulders. Special designs available to provide electrical contacts, spacers, for economy molding practices.



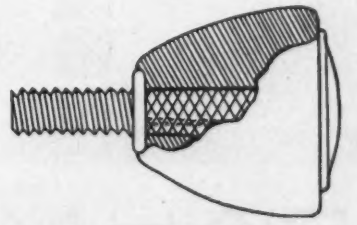
34. When molding insert screws in hard rubber, a shoulder seals the part in.



35. Special straight fluted or knurled sections present easy press-on assemblies to combine insulating plastic knobs for proper final designs.

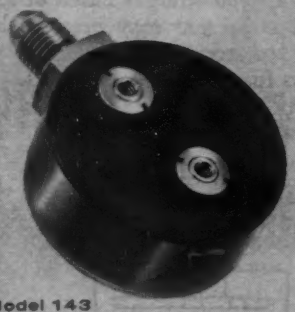


36. For thin sections of rubber moldings, shoulder of insert locks mold against leakage onto threads. Low type head has indented sections to resist rotation and broad pressure surfaces fo rstrength. Brass plated for better (improved) vulcanized bond.



37. Applying threaded or rivet type inserts to plastic knobs is simple with a shoulder to locate insert correctly in mold. Coarse diamond knurl prevents rotation. Threaded or riveting ends are available.

PRESSURE TRANSDUCERS



Model 143

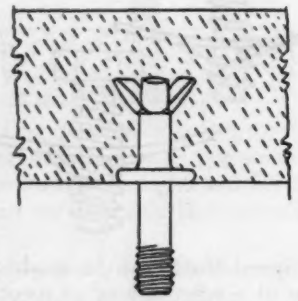
MISSILE, AIRCRAFT AND INDUSTRIAL APPLICATIONS

• Guaranteed noise free signal under high vibration • Long Life • Infinite Resolution • Available as a standard in all pressure ranges •

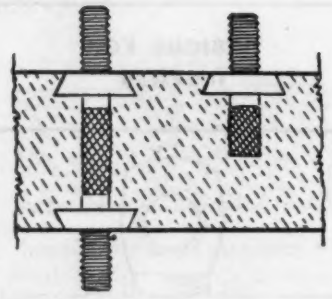
RAHM
INSTRUMENTS
DIV. OF AMERICAN MACHINE AND METALS, INC.
65 Rushmore St., Westbury, N. Y.
EDgewood 3-4840

CIRCLE NO. 48 ON INQUIRY CARD

DESIGN TIME SAVER

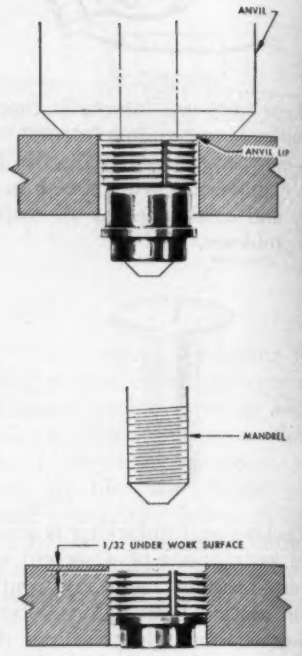


38. Specially split top metal sections plus sealing collar permit great freedom of design with all types of thermoset materials. No cracking of plastic material yet positive protection against both rotation and pull out.

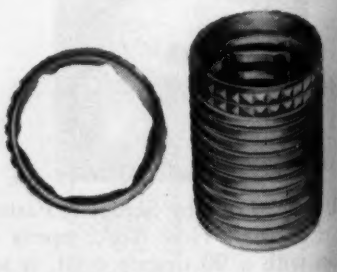


39. Special tapered designed shoulders (single or double) offer the complete answer to successful product design, greatly reduced mold cost and freedom to choose several different thread diameters.

40. "Heli-Coil" Screw-Thread Inserts and Screw-Lock Inserts are available for original equipment design applications, and in their Shop-Pack form can be applied to prototype experimentation. "Heli-Coil" Screw-Thread Stainless Steel Wire Thread Inserts are available in National Coarse and National Fine Series up to 1½" in Screw-Thread and 1" in Screw-Lock. Meets MIL and NAS specs for locking torque and vibration.

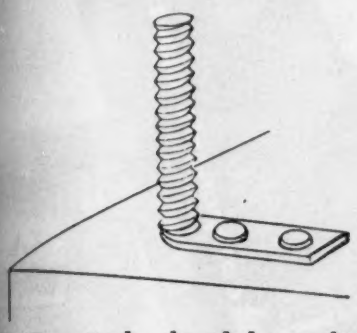


41. Stainless Steel inserts by Hi-Shear Rivet Tool Company, Torrance, California, are used in designs calling for load bearing, wear resistant self locking threads for use in materials such as plate or cost aluminum. The principle of assembly is to pull the internally threaded expander into the externally grooved sleeve which is prepositioned into a drilled work hole. Meets MIL-N-25027 (ASG).

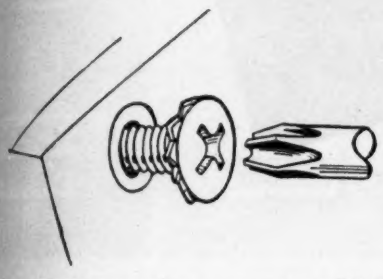


42. SLIMSERT, developed by Rosan, Inc., of Newport Beach, California, is a thin well locking insert that exceeds MIL-N-25027 specs. It has a wide temperature range, light weight, positive external locks, minimum edge distance and resistance to corrosion. Internal thread lock is standard in aircraft series only. Installed in two gadget free operations.

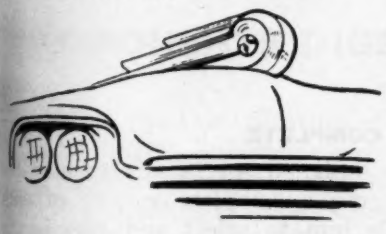
DESIGNS FOR SAFETY



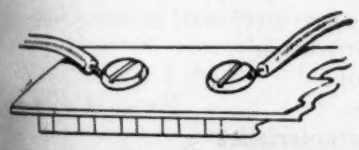
43. To attach threaded members smoothly to metal or other material, use either welding or riveting double duty special studs for added safety and security.



44. Lock washer pre-assembled screws protect against vibration.

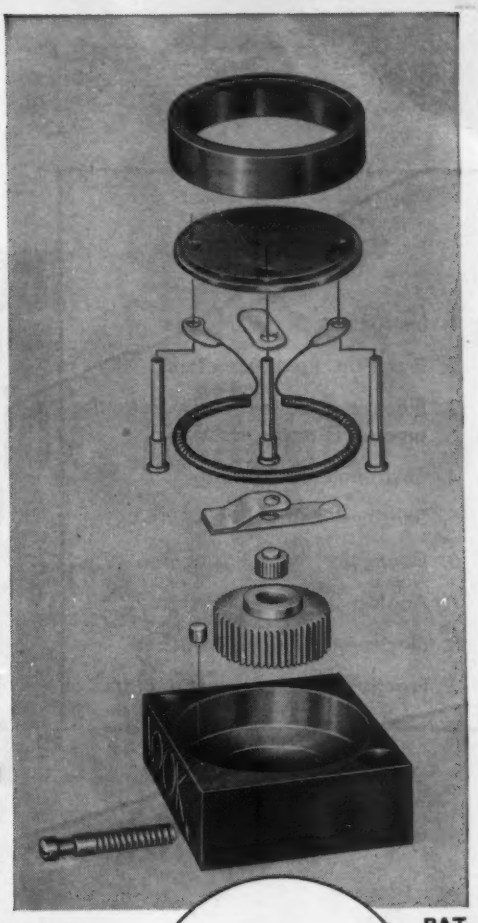


45. One-way head screws protect attachments, offer low cost theft discouragement.



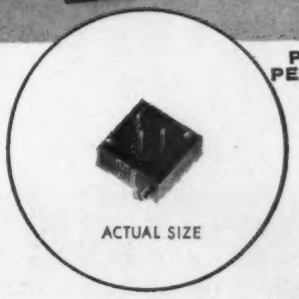
46. Undercut straight side binder head screws protect braided electric cable against "shorts" due to fraying wire.

47. Combination of two features applied to a TV set design: (patented) Ilolt head slots stop homeowners meddling and spinlock insures further against do-it-yourself dangerous tampering.



NEW! TAKE A LOOK AT THE GUTS OF HANDLEY'S WEETRIM POT

PAT. PEND.



...the Precision Trimming Potentiometer that will Standardize the Industry The Handley WeeTrim trimming potentiometer will standardize the type...and, as with other Wee Line products, WeeTrim is manufactured under strict quality control. Lightweight, wee in size, extremely stable, and WeeTrim has the other exclusive Handley Wee Line features. Write today! Literature will be provided immediately.

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Pine Brook

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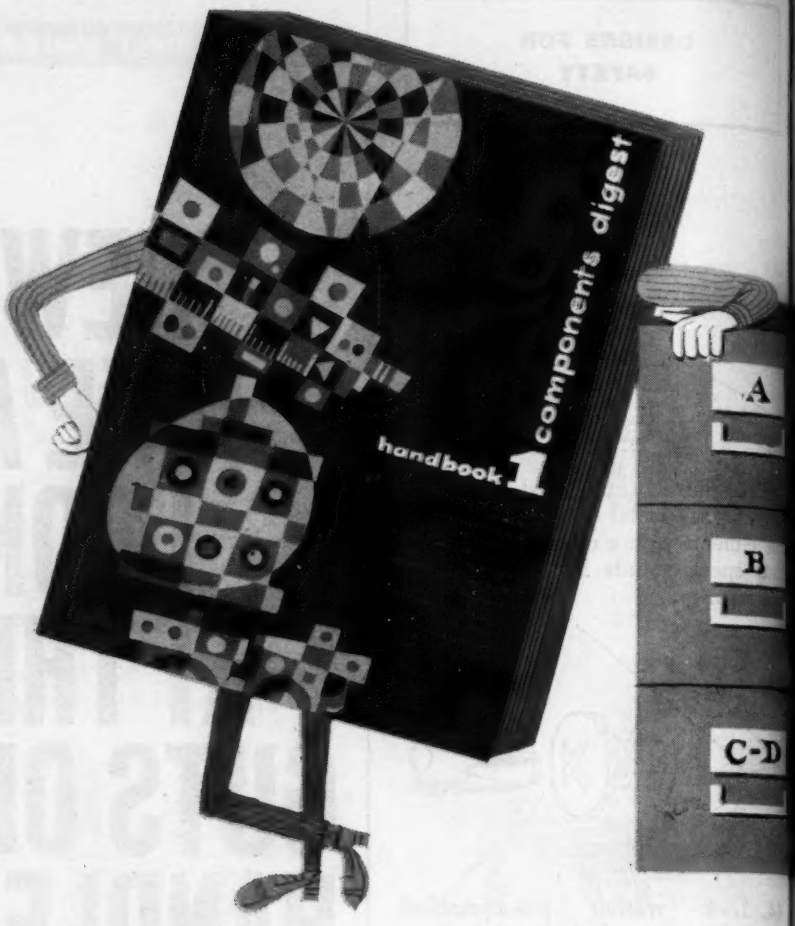
TEXAS
Koch Engineering & Sales
309 Meadows Bldg., Dallas 6

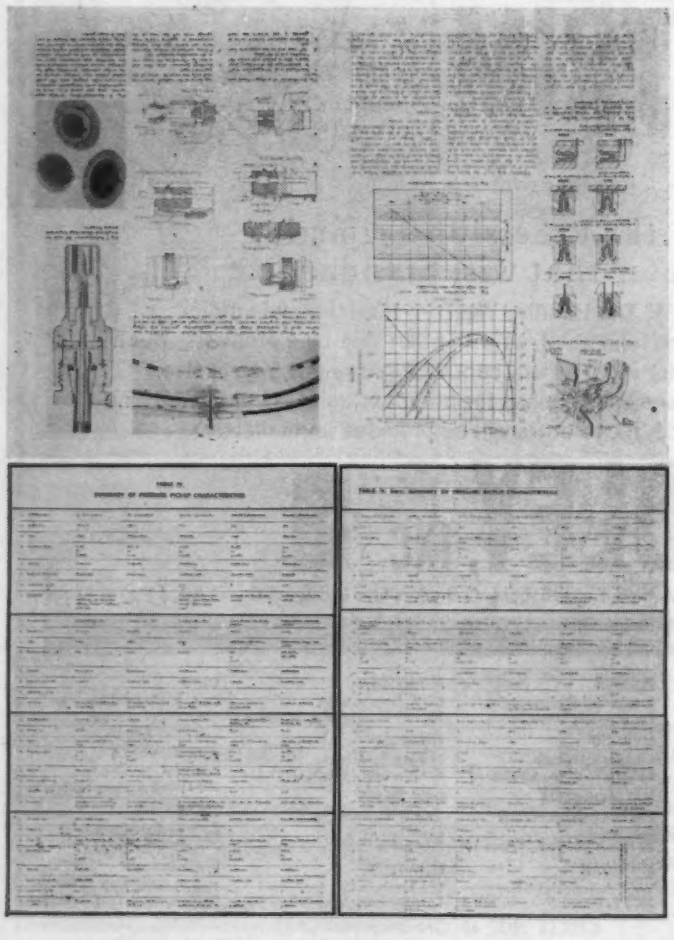
WASHINGTON
Howell Sales, Inc.
2029 McGilvra Blvd., Seattle 2

CIRCLE NO. 49 ON INQUIRY CARD

CONTENTS OF HANDBOOK NO. 1

1. Instrument Servo Motors
2. Precision Potentiometers
3. Electromagnetic and Potentiometer Transducers
4. Environmental Testing
5. Sensitive Relays
6. Connectors and Fasteners
7. Analog-Digital Converters
8. Electromechanical Switches
9. Fractional Horsepower Motors





PRACTICAL AND COMPLETE

This handbook is designed specifically to give the busy design engineer a complete survey of each subject. To enable him to select and specify the proper components.

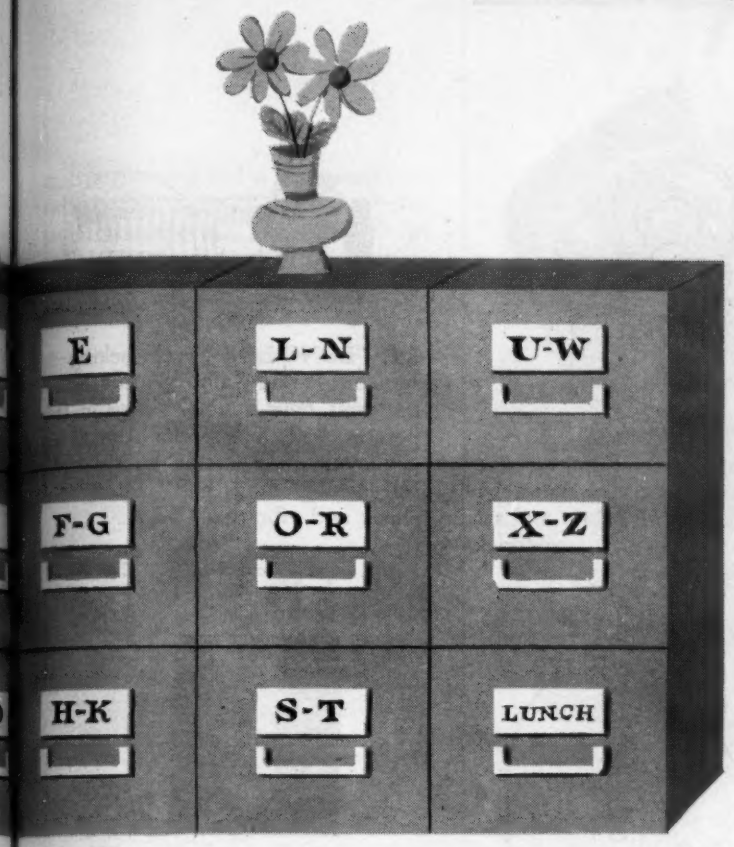
Each category is thoroughly examined and documented. You will find complete

Descriptions of types, sizes and measurements
Construction Information
Design Applications
Selection Factors
Performance Characteristics
Military Specifications
Reliability Assessments
Nomenclature and Definition tables

Every subject is extensively illustrated with photos, charts, tables, diagrams and exploded views of components and their performances.

If you were to assemble all the data from all of the sources involved it would fill four filing cabinets and require an assistant to keep it in proper order.

We hold no animosity against filing cabinets or girls. Quite the contrary! That is the ideal way to process information. If, however, your budget doesn't permit such luxurious facilities, Components Digest Handbook No. 1 will afford equal efficiency with no distraction whatsoever.



Four (4) filing cabinets in one handy handbook

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Response from our readers has been overwhelming.

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"First time I have had all of the information at my finger-tips."

Many of the comments ended with this request.

"Why not combine these digests into book form."

That's what we've done. Collected nine (*see contents list on opposite page*) of these exhaustively researched studies and bound them together into COMPONENTS DIGEST HANDBOOK NO. 1.

It makes a rich sourcebook of design information. One that neither you nor your company can afford to be without.

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Type 3173
⅞" dia. rotary

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When the ultimate in quality and reliability is required . . . when there is no time for standby or interruptions . . . no room for component value variations . . . no tolerance of failure — then it's high time to specify MARKITE precision potentiometers. Here are only a few reasons why they provide performance beyond the expected:

• Linear stability for more than 50 million cycles • Substantially infinite resolution • Independent linearity to 0.05% in 1 5/16" dia. units and 0.01% in 5" dia. units • Operation in ambient temperatures up to 200° C • Shock and acceleration resistance in excess of 100g • Rotational speeds up to 1,000 rpm • Meet Military Specifications.

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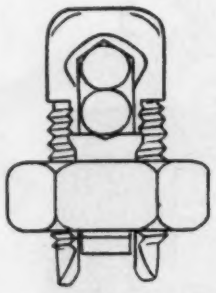
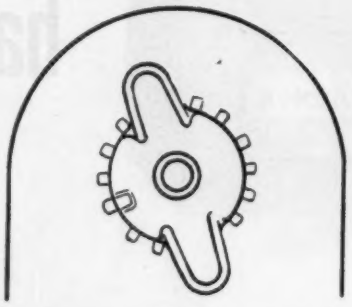
CIRCLE NO. 18 ON INQUIRY CARD

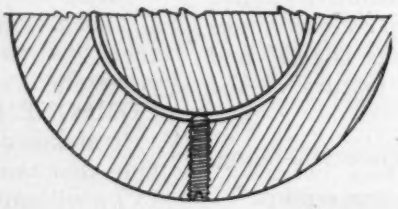
DESIGN TIME SAVER



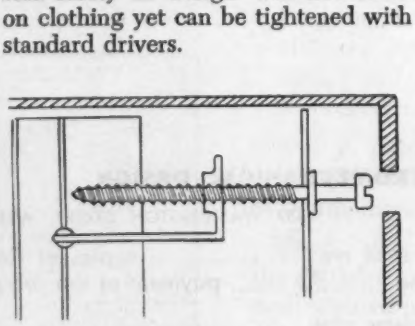
48. A unique cold heading job reduces production costs; pressure bar of special bronze insures safe and satisfactory locking means for solderless wire connections.



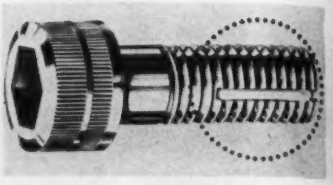
49. Locking notch protects against slipping adjustments. Small depression built into design fits corresponding notches provided on wing nut.



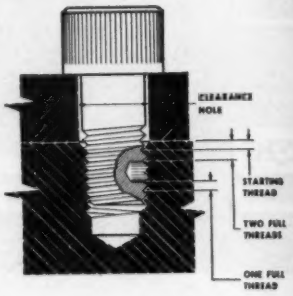
50. This special headless Phillips recessed ball pointed set screw offers real safety in design—will not catch on clothing yet can be tightened with standard drivers.

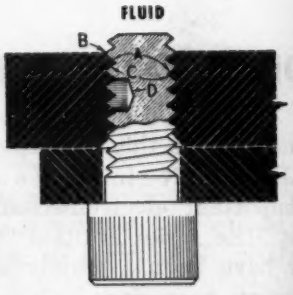


51. A rare combination of design and cost saving simplicity. Special double collar and fast lead thread permits quick adjustment while depressed head design guards against tampering.

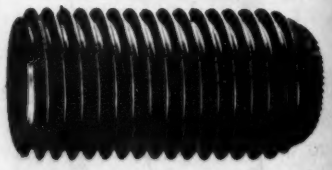


52. "LONG-LOK", self-locking insert on Parker-Kalon Socket Screws performs over a wide range of temperatures with superior thread engagement, high torsional resistance, a self-locking drag and resistance to shock and vibration.





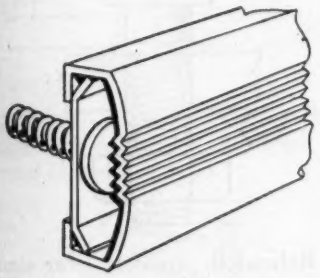
53. Socket screws make use of a compressible nylon pellet to insure positive holding power despite shock and vibration. The pellet compresses as the screw advances forcing mating threads together for positive gripping. Fasteners are reusable, will stay locked at any depth without sealing (and so can be used for adjustments) and will seal against liquids and gases at moderate pressures.



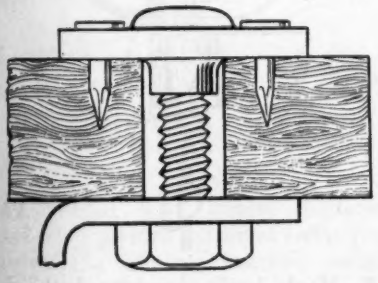
54. A high torque Unbrako socket set screw made by Standard Pressed Steel Co., Jenkintown, Pennsylvania, has a knurled cup point for positive self-locking. Fully formed threads maintain continuous grain flow, pro-

venting shearing and a controlled root radius adds strength. Deep socket provides maximum key engagement and wrenching power. Meets applicable mil specs.

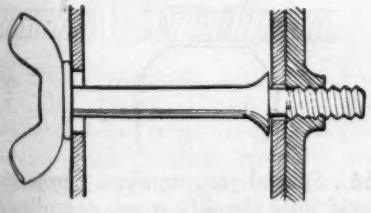
DESIGNS FOR SIMPLICITY



56. Molding screws requiring large head spans—provide for simplicity in assembly.



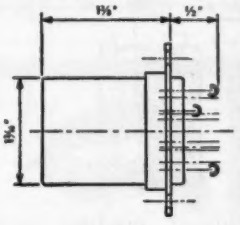
57. Applying internally threaded fasteners to wood simplifies assembly problems when adjustments or removal features are required.

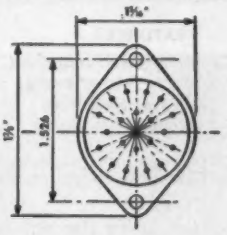


58. Simple combinations of extended adjustments available through reheading methods; collars can be applied at varied locations along threaded shanks.

The First...

wedge action relay





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Insures ULTRA-reliability under most extreme environmental and operating conditions.

Revolutionary new WEDGE ACTION supersedes and surpasses "Wiping Action."

Contact pressure constantly increases during over-travel.

- **Temperature range: – 65°C to 200°C.**
- **Contact bounce: NONE.**
  Operating vibration: 5 to 2,000 cps, 30 G's.
  Operating shock: 100 G.
- **Contact rating: dry circuit to 2 amps.**
- **Extremely low contact resistance.**

BRIEF DESCRIPTION: Six pole, double-throw, hermetically sealed. Meets and exceeds specifications MIL-R-5757C and MIL-R-25018.

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ELECTRO TEC CORP. SLIP RINGS • SWITCHES RELAYS

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CIRCLE NO. 51 ON INQUIRY CARD

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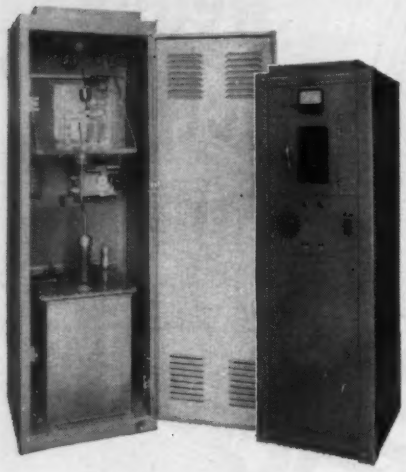

AC BREAKDOWN TESTERS

Complete line of units designed for testing in accordance with ASTM D-149 and Federal Spec. LP-406, Method 4031, used for determination of dielectric strength and breakdown voltage safely, simply and accurately in the laboratory or on the production line.

FEATURES

- Completely self-contained
- Automatic rate of voltage rise
- Plug-in test electrodes
- Retention of voltmeter reading after breakdown
- Dual range units available for maximum versatility, up to six voltmeter ranges

In addition to the standard models noted below, special models incorporating higher output ratings and a number of metering systems including primary metering, direct secondary metering, and digital output with recording can be provided.

SINGLE		DUAL
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PA-5-155	PA-5-502	PA-5-252/052
PA-5-252	PA-5-505	PA-50-1005/205
PA-50-1005		

ARC RESISTANCE TESTER

Used for measuring the ability of insulating material to withstand high-voltage low-current arcs. Supplied in conformance with ASTM D-495 and Federal Spec. LP-406 Method 4011.2. Simplified operation includes automatic stepping and timing, and improved electrode holder. Operable by unskilled personnel.

Complete catalog of Electrical Test Equipment available on request.

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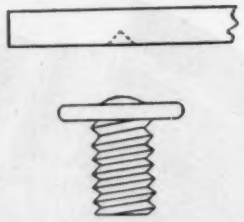
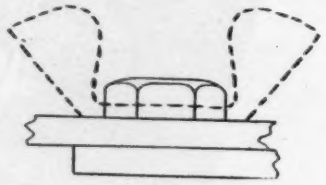
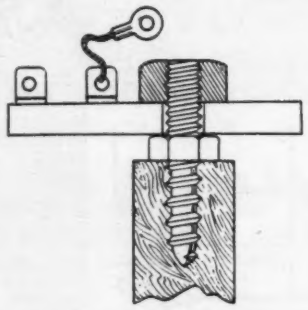
DESIGN TIME SAVER



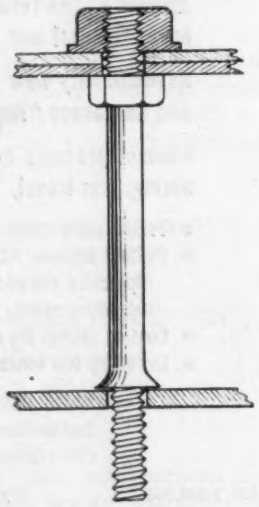
59. Single point, one sided welding fasteners simplify assemblies in attaching threaded members to metal plates.



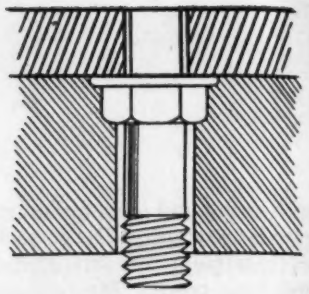
60. Simplicity and economy are both obtained when small wrenches are needed for adjustment, especially when given away with products.



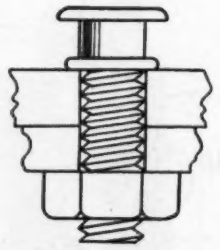
61. For attaching machine screw threads to wood sections—special hexagon collared fasteners are available to meet all applications, offering a simple and inexpensive design.



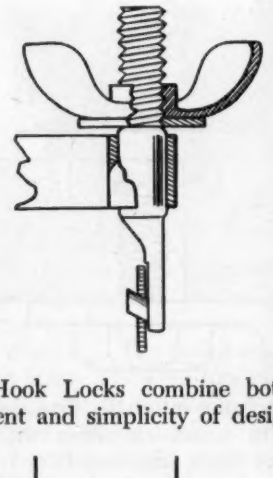
62. Spacer requirements can be both simply and economically made by applying reheaded products, guaranteeing spacing limits at all times.



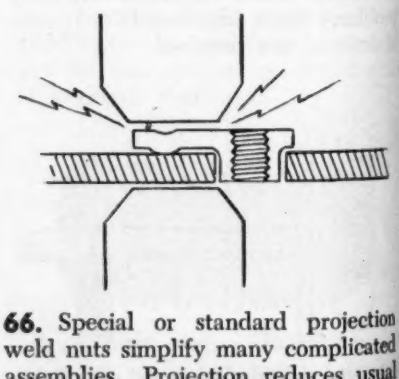
63. Special copper or bronze electrical contact screws simplify both designs and assemblies of many complicated electrical switches. Hexagon and square shoulders resist rotation and smooth, well-developed upper contact surfaces provide many required combinations. Special points offer faster assemblies at no increased costs.



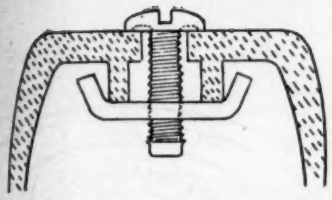
64. Reheaded products offer simple means of applying spacers or latch assemblies.



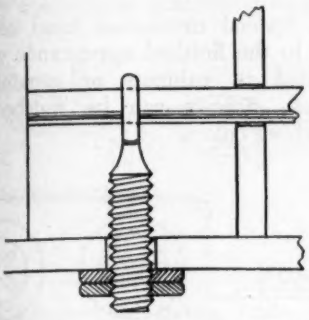
65. Hook Locks combine both adjustment and simplicity of design.



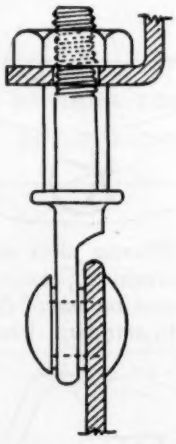
66. Special or standard projection weld nuts simplify many complicated assemblies. Projection reduces usual spot welding costs, special extruded section not only locates unit but definitely protects against welding flash eliminating all retapping operations.



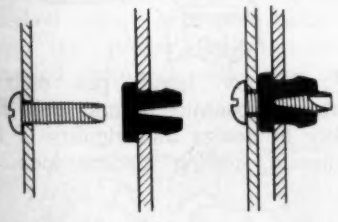
67. Here is simplicity plus dollar savings. A spring steel stamping—tapped, heat treated, a special plated screw assembled, staked over and backed locked to a guaranteed inch pound bread-out torque.



68. Simple adjustments of rods or tubing are able in flattened and pierced closed eye bolts.



69. Special heat treated flattened and relief pierced extruded collar stud provides a genuine assembly saving as a swing pivot.



70. Plasti-Grommets made by Fastex, Des Plains, Illinois, are self-retaining, blind screw receptacles that provide high holding strength and high load carrying capacity. They are easily snapped in place, lock tight and provide insulation at the fastening and corrosion resistant. They also accommodate mi-alignment, act as spacers and assure freedom from squeaks.

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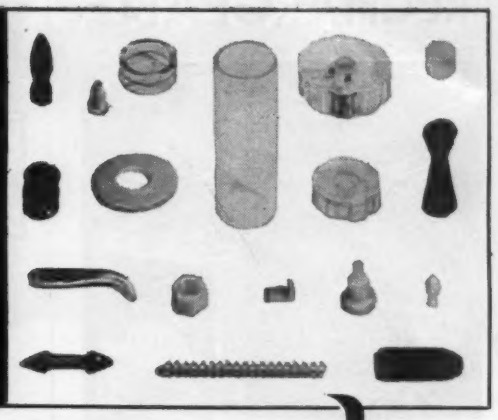

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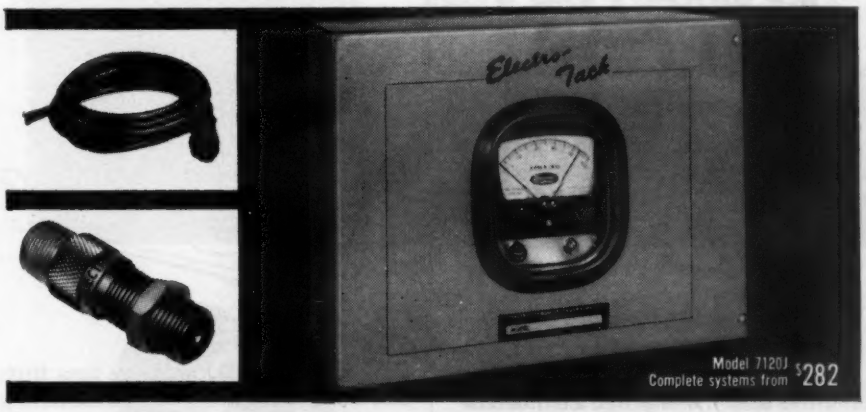

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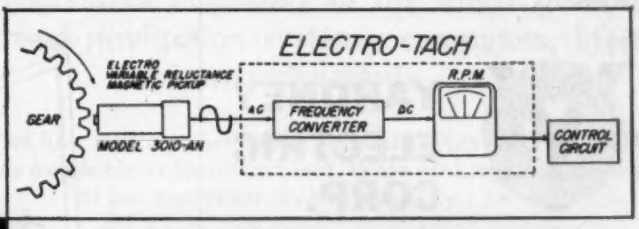
Adjustable Speed Control with meter accuracy of 2% full-scale reading.



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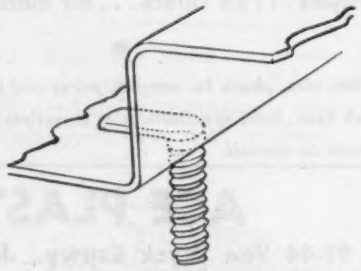
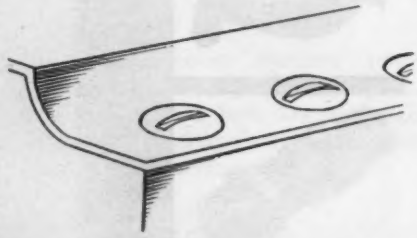
DESIGNS FOR APPEARANCE

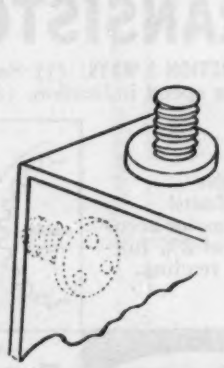
71. Neat appearing Phillips recessed head on hardware enhances appearance of finished product.



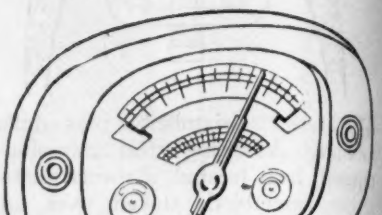
72. Offset welding screws provide ideal means to maintain smooth appearance in hard-to-assemble offset applications.



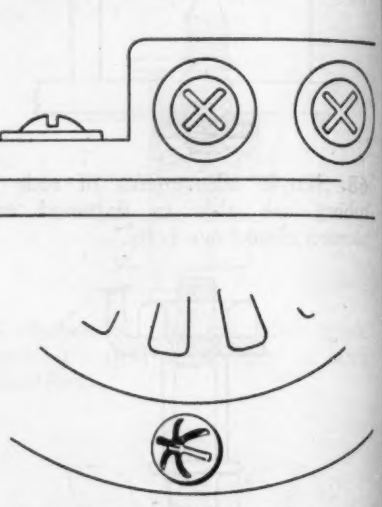
73. The smooth, low, large area truss head screw improves the streamlining of products which require outside assemblies, improving general appearance.



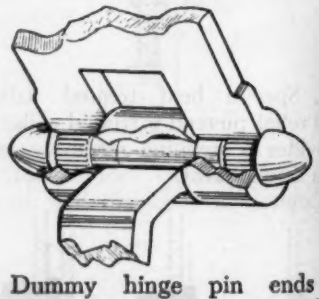
74. Inside welding assemblies of threaded members maintain a neat looking finished product.



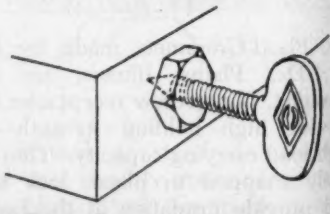
75. Special decorative head screws add to the finished appearance when applied to cabinets or escutcheon plates. Screws can be finished in matching colors.



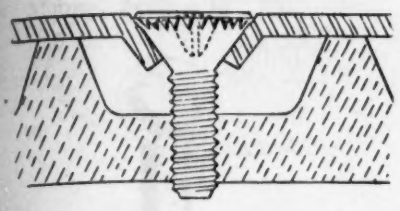
76. Special cross slots and tri slots improve general appearance of products that must be assembled from the outside with standard drivers.



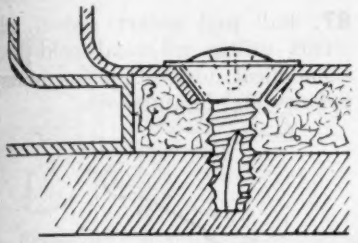
77. Dummy hinge pin ends of matching contour permit great flexibility in design and rigidity of construction, adding modern look.



78. General customer acceptance of products requiring adjustments can be increased by providing a neatly coined thumb section.

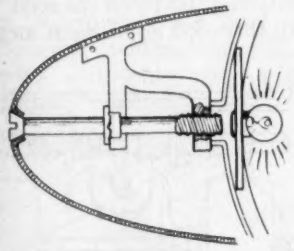


79. Special locking "Spin lock" screws with Phillips recesses are provided with outer rim to appear as if they are set into a finishing washer.

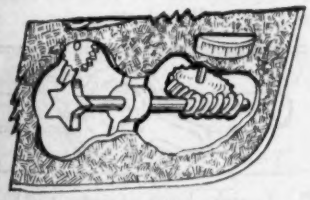


80. Illustration shows how added appearance with economy in assembly is obtained by Sems finishing washer applied when washer should turn on final assembly.

DESIGNS FOR ADJUSTMENT



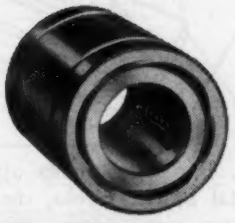
81. Locking adjustments requiring double spacing are well provided in specially designed reheaded products. Notched collars offer permanent settings for proper adjustments of threaded members with freedom of design.



82. Gears, worms and other accepted means of counting or adjusting can be combined in specially designed threaded and trimmed products, offering many combinations for flexibility.

CIRCLE NO. 53 ON INQUIRY CARD

...*for* **MINIATURIZATION**



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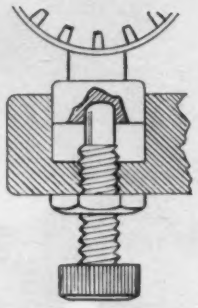
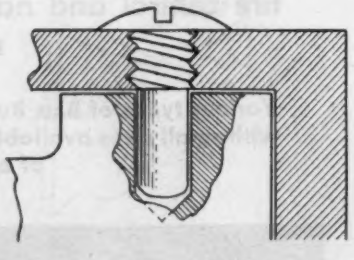
DESIGN TIME SAVER



83. Knurling and special pointed bearing surfaces may be combined to permit smooth, inexpensive pressure adjustments for all field problem requirements.

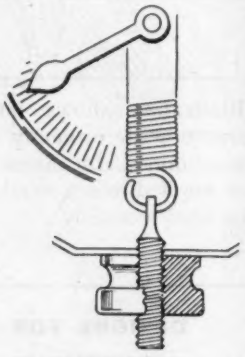
84. Specially designed threaded and flattened members offer both positive thinline welding crossbars plus location lugs. These designs offer ideal tightening members for large hard-to-handle stampings.

85. For adjustments against slotted metal bracket areas, shoulder thumb screws give simple, inexpensive yet adequate thumb adjusting locking surfaces.

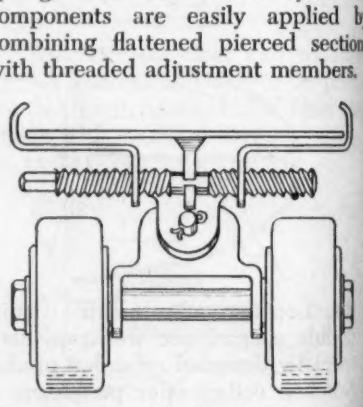


86. Applying special hinge pins or swivel assemblies with threaded members, cold headed, rolled thread shoulders, answers design questions for variation of diameters. Adjustment assemblies of great variety are possible.

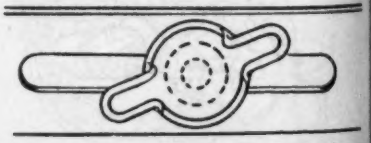
87. Ball and socket swivel adjustments utilize spherical cold headed economical designs for maximum efficiency and latitude.



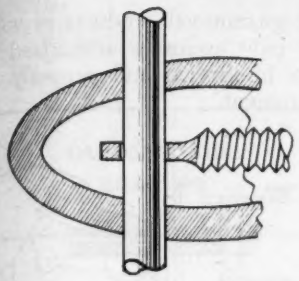
88. Adjustments for controls using springs and other similarly ended components are easily applied by combining flattened pierced sections with threaded adjustment members.



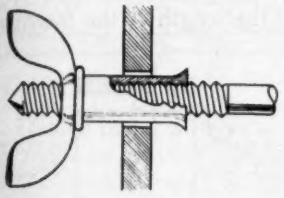
89. Threaded adjustments using both right and left hand opposing threaded members offer ideal clamping applications as you should remember from roller skating days.



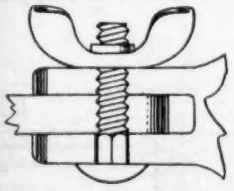
90. Large base (patented) thumb screws providing both ample wing spread and special (pre-assembled Sems) free spinning flat washers offer many quick adjusting means for grooved and/or slotted members of assembly designs.



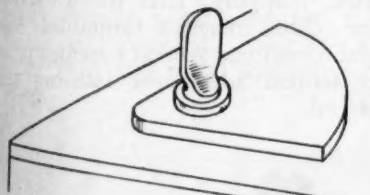
91. Adjustments of rods and tubing with assembly facilities provided by special flattened and pierced eye bolts concentrate tightening power over small area in permanent type fasteners.



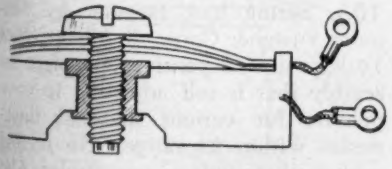
92. Extended wing nuts can be spun over and locked in place permitting varied adjustments on threaded members which are free to go through sections of covers.



93. Simple applications requiring frequent adjustments are easily obtained by using combination of shoulder screws and wing nuts against stampings and castings.



94. Inspection covers and similar applications utilize shoulders applied to thumb screws for adjusting or tightening means.



95. Close tolerance fine adjustments are available in roll threaded products. Illustration shows part with 64 threads per inch for tightening and/or adjusting electromechanical mechanisms.

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☐ SIMPLIFY ASSEMBLY
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Thumb Nuts
Thumb & Wing Screws
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Hex Nuts
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now . . .
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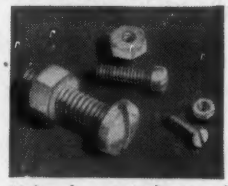

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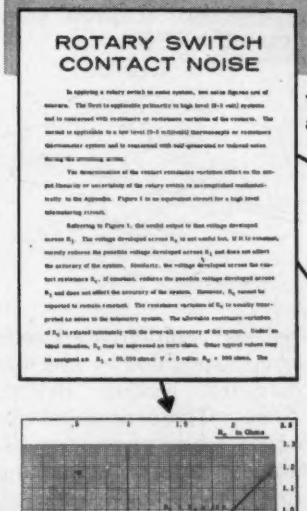
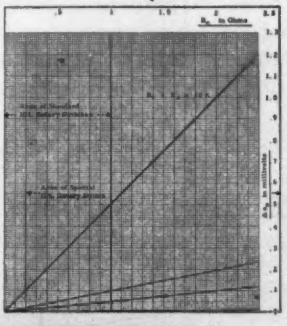
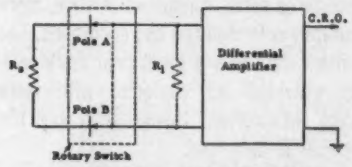
How Do YOU Define Switch Noise?

Here's how IDL analyzes it!

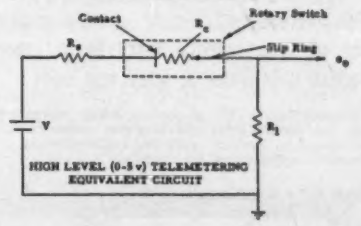




These data are important considerations in switch applications and provide you with valuable criteria for systems evaluation.



LOW LEVEL (0-5 mv or 0-50 mv) TELEMETERING EQUIVALENT CIRCUIT



HIGH LEVEL (0-5 v) TELEMETERING EQUIVALENT CIRCUIT

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By combining several environments in **one** single test you get more **factual** information.

For instance we recently combined high intensity acoustic vibration, high temperature and mechanical vibration into one fully instrumented chamber to test a component. These three tests, conducted at once, more accurately reflected the use conditions. The resultant data was a great deal more realistic, provided our customer with **more** factual information. Needless to say the customer is delighted.

Why not let us tell you about Roto-Test's Poly-vironmental* Testing . . . the combining of environmental tests to get more factual data under optimum use loads.

Complete facilities for: all standard military environments, plus high intensity sound, cine-radiography, random vibration, and others for electrical, electronic, electromechanical, and pneumatic components and sub-assemblies.

*Trade Mark Roto-Test Laboratories, Inc.

Rototest laboratories inc.

2803 Las Flores Blvd. Lynwood, Calif.

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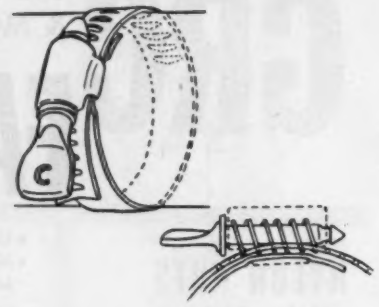
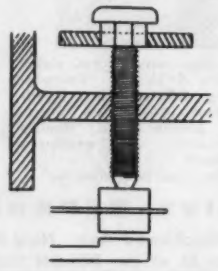
DESIGN TIME SAVER

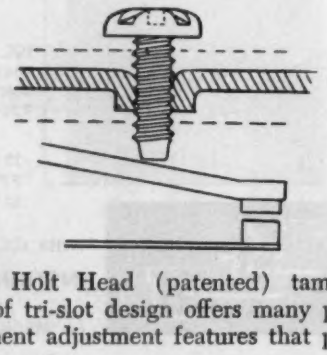


96. Special buttress or other thread contour designs can be developed for extremely accurate adjustment of clamps, bands and/or depth tightening. These special thread designs may be either thumb or driver adjusted.

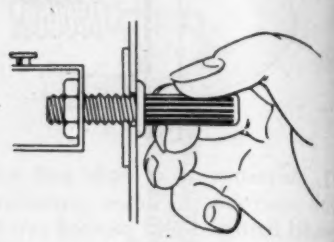


97. Extra fine rolled threads, shown 10-64 threads per inch applied to special copper or bronze threaded members permit great latitude in design without added costs of special ground or extra class thread fits.

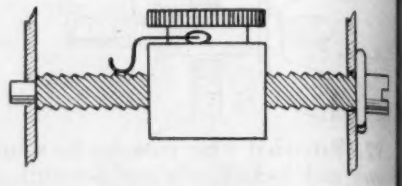
98. Large and multi-grooved assemblies are best assembled by specifying large diameter locking Belleville washer Sems. These modern vibration proof assemblies guarantee maximum tightening torque at minimum engineering and assembly costs.



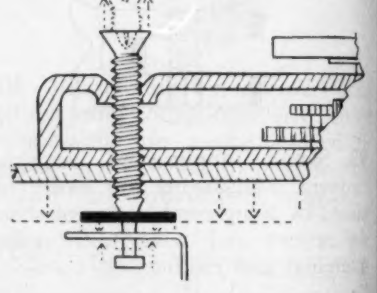
99. Holt Head (patented) tamper proof tri-slot design offers many permanent adjustment features that protect guaranteed products or will permit only exclusive authorized repair men to service and properly adjust equipment.



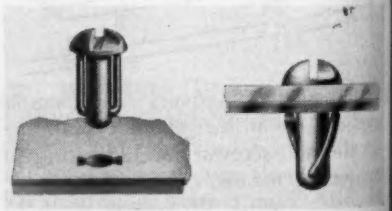
100. Thumb adjustments for snap switches, etc., utilize cold heading ability to place shoulders anywhere along the length of the fastener.



101. Multi-lead screws can be rolled to obtain almost any speed of adjustment or timing required for both electrical and mechanical applications.

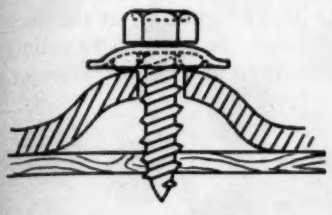


102. Shipping "hold down" screws for rubber mounted turntables. Special turned end section provides proper tension adjustment insuring safe arrival.

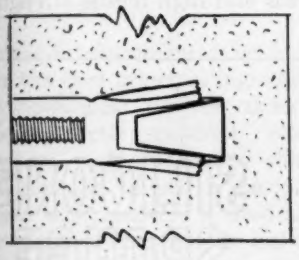


103. Spring lock fastener by Simmons Fastener Corp., of Albany, New York, is an inexpensive one piece assembly that is self adjusting to compensate for various material thicknesses within its range. No mating parts such as nuts or receptacles. Also permits its use as a "blind" fastener. It locks and unlocks with a quarter turn or can be permanently installed. Sheets are locked with high initial loan in a tight, vibration-proof, deflection free assembly.

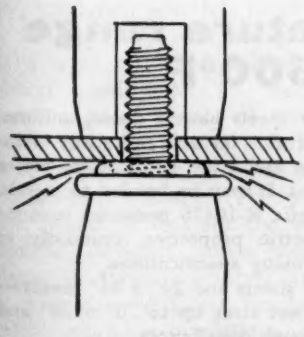
DESIGNS FOR SEALING



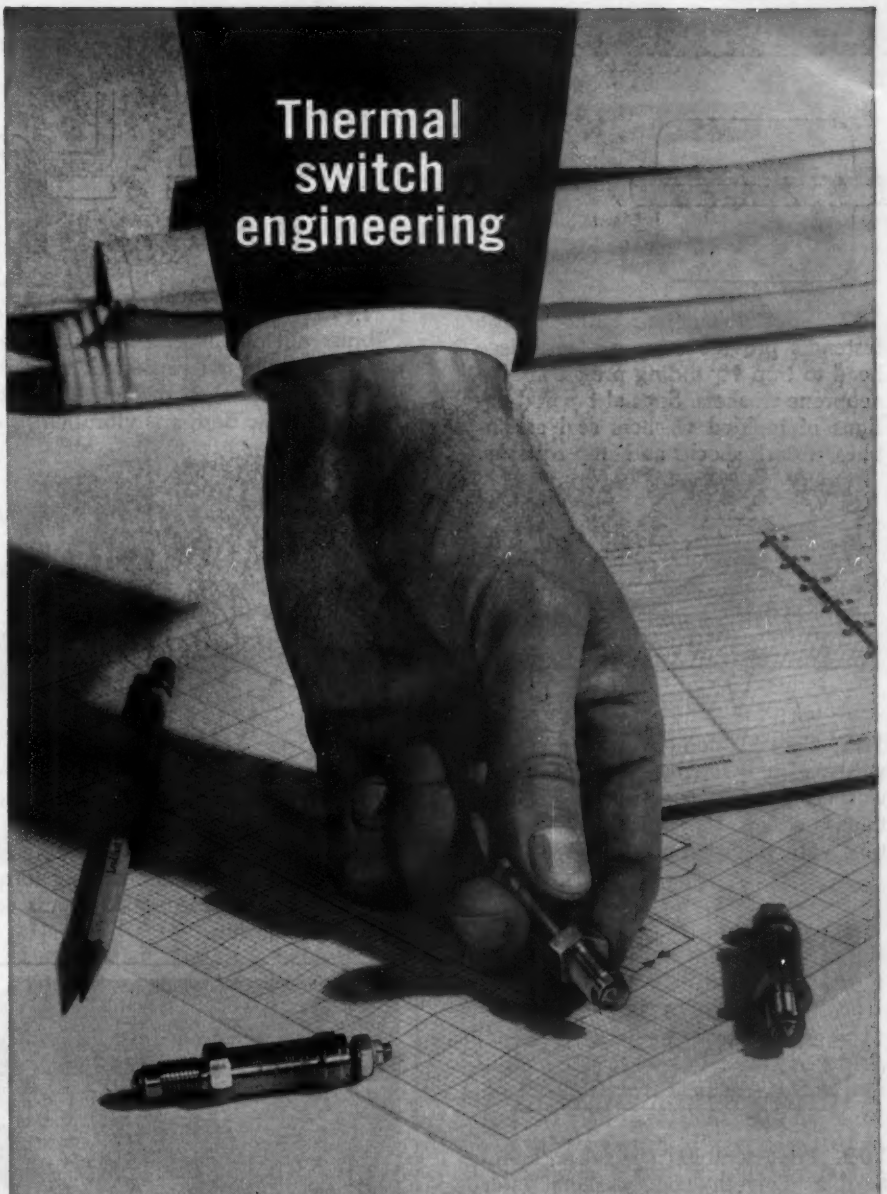
104. Domed metal washers with flattened perimeter, having a stable nonaging compound bonded to undersurface, provide leakproof assemblies against all liquids and vapors. Withstand temperatures from −100° to +250° F. without change. Pre-assembled to screws with all head styles for economical assemplies.



105. Smooth tapered expanding plugs answer many assembly problems in masonry, concrete and other lead and metal anchoring devices.



106. Special continuous ring designs for welding screws permit permanent sealing of welded assemblies against oil, water or other liquids. Rings may be placed on top of head or under section as illustrated.

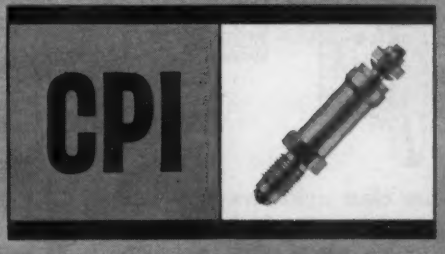


"TIP TEMPERATURE" RESPONSE SWITCH FROM CPI RESEARCH

This is a new precision thermal switch designed to act as a warning device in controlling temperatures in aircraft generators. But that is only part of the story. This CPI switch responds to tip temperatures rather than shell temperatures. For that reason it's called the "Tip-Stat". It now joins the growing CPI family of high quality, custom, precision thermal switches.

There's a good chance that this switch or a modification of it can solve your thermal control problems. If not, CPI engineers can create a new switch that does. In either event, why not tell us about your thermal control problem now?

This hermetically sealed switch has spring loaded inner cartridge, can be "bottomed" in hole under considerable tip pressure; calibration range is −20F to 550F; safe momentary overshoot to 600F; reaction time, less than 0.5 seconds. Mention "Tip-Stat" when inquiring.



CONTROL PRODUCTS, INC.

308 Sussex Street, Harrison, N.J.

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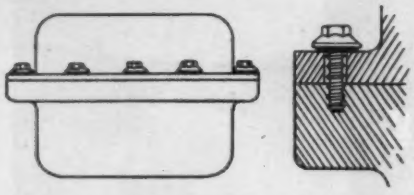
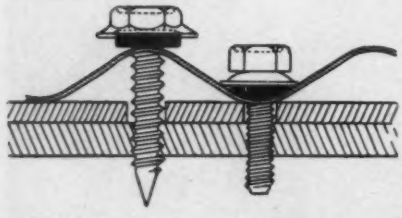
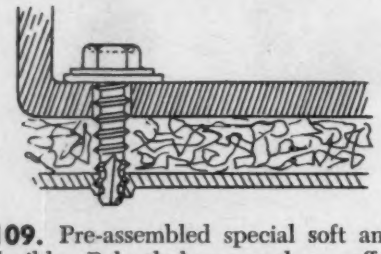
DESIGN TIME SAVER



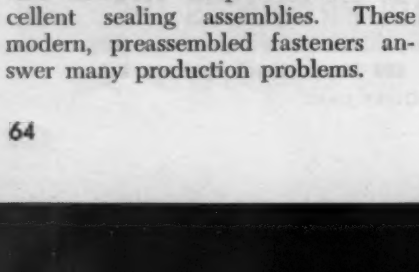
107. Special TuffTite multi-purpose fasteners provide undercut one piece head to trap expanding pre-assembled neoprene washers. Special tapered designs of molded washers seal assemblies, absorb shocks and stop squeaks.



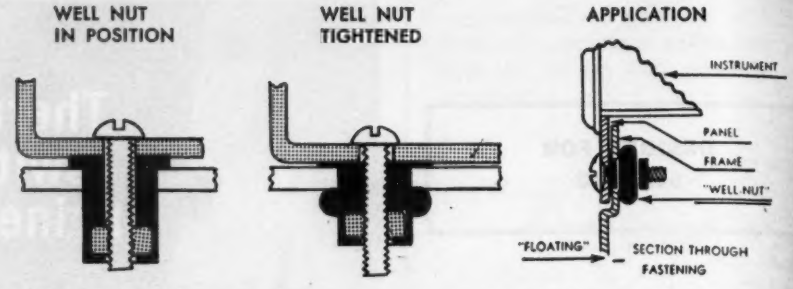
108. Special domed shaped metal washers and separate cut neoprene washers provide excellent sealing fasteners where the washer does not turn with the rotation of screw head.



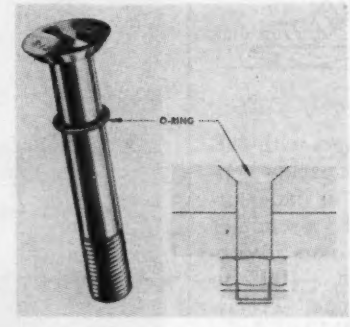
109. Pre-assembled special soft and flexible Polyethylene washers offer permanent sealing assemblies in both metal to metal or plastic to metal designs. Insure against enamel cracking, excellent for designs involving cold temperatures such as refrigeration or deep freeze units.



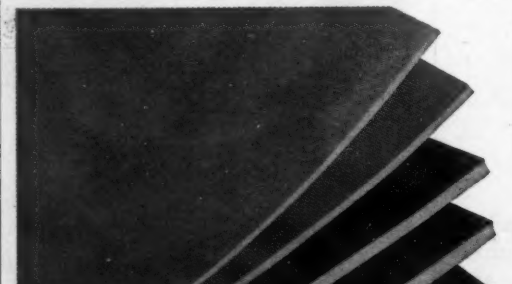
110. Thin clear nylon washers with either low or medium-high temperature resistance composition offer excellent sealing assemblies. These modern, preassembled fasteners answer many production problems.



111. Well-Nuts consist of a tough neoprene bushing with a bonded brass nut at one end and a flanged shoulder at the other. Turning the screw in the nut causes the neoprene to be drawn tight against the back of the material in the form of a stray rivet head. In addition to sealing function the design is vibration proof and functions as a "blind" fastener.



112. Hi-Torque sealing bolt designed by Hi-Shear Rivet Tool Company, Torrance, California, can be applied with a rubber "O" ring that fits under the head of the bolt. Specialshallow-cut recess is undercut at the rides where the driving torque is applied. Fastener delivers optimum torque values, good recess contact areas and high tensile strength and fatigue life.



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Flexible temperature range -100°F to 500°F

COHRlastic R-10470 silicone sponge rubber sheets have a dense, uniform, non-absorbing closed cell structure highly suitable for soft gasketing, vibration dampening, fairing strips, pads, cushions and other applications where resiliency at extreme temperatures is required. It may be bonded to metals, plastics, fabrics or silicone rubber. COHRlastic R-10470 possesses superior compression set resistance, excellent dielectric properties, immunity to aging, ozone and weather hardening. Meets many specifications.

AVAILABLE FROM STOCK: in 12″ x 12″ sheets and 24″ x 24″ sheets — 1/16″ through 1/2″. Special thicknesses and sheet sizes up to 30″ x 30″ and 24″ x 48″ made to order. Sold nationally through distributors.

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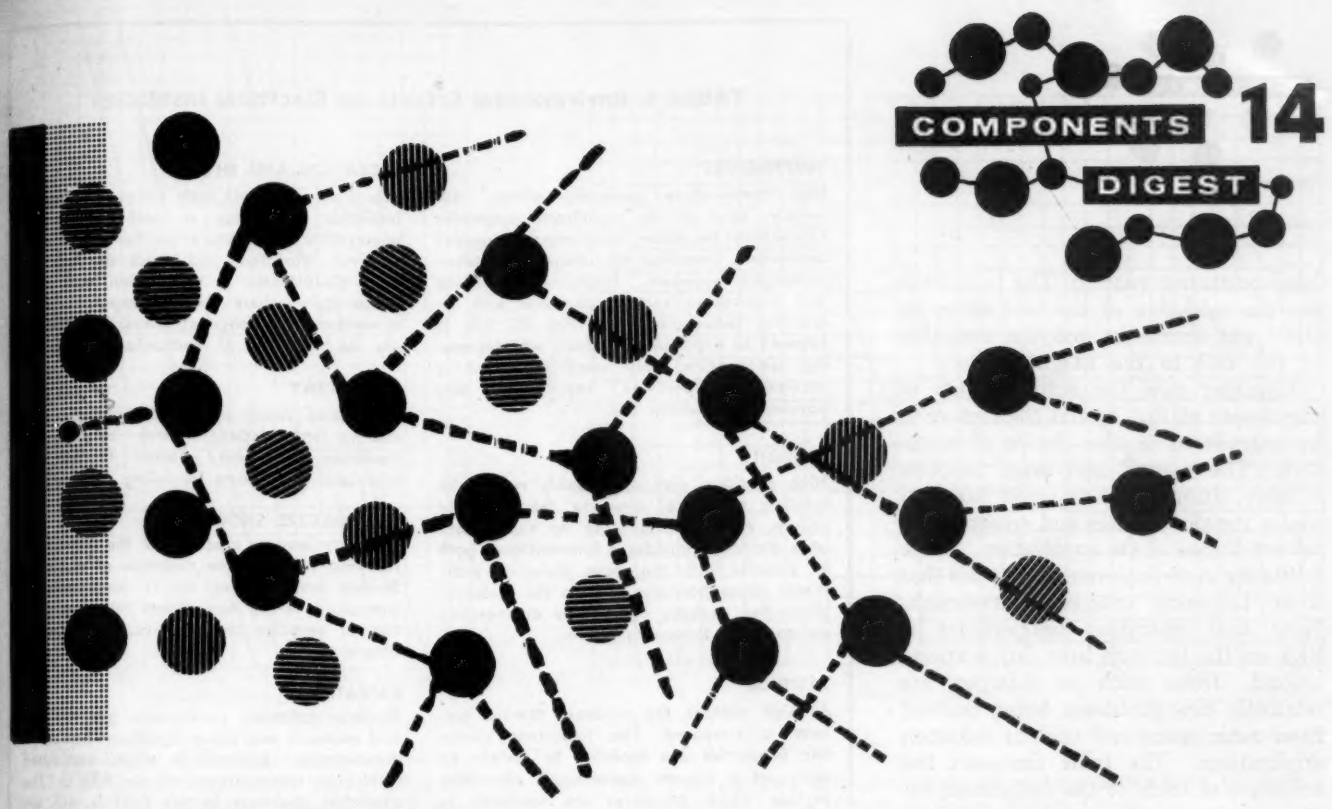


Electrical Insulation

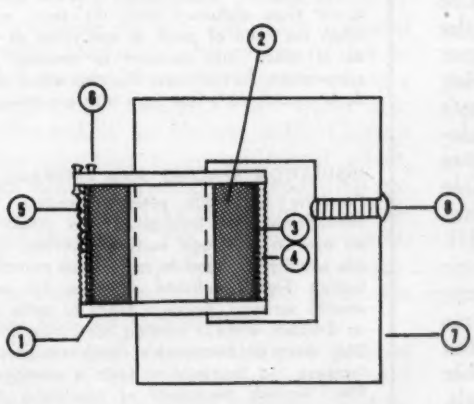
Electrical insulation must be included among the four principal ingredients of electromechanical devices along with magnetic circuit material, electrical conductors, and mechanical elements. In the past the variety of electrical insulations was relatively limited and selection factors were simple, but recent trends in the design of electromechanical devices have substantially altered insulation problems. These trends are principally:

- Emphasis on miniaturization.
- Severe environments imposed by military and many new industrial applications,
- Emphasis on reliability.

Briefly, insulation now has to work reliably in extremely compact packages under a wide range of difficult environmental conditions. To meet this challenge a great variety of insulation types has been developed with a wide range of physical and chemical as well as dielectric properties. The purpose of this Digest is to help the electromechanical designer solve insulation problems in these advanced applications. Although we do not list the commercially available insulations, we do point out factors to consider in making intelligent selections.

THE INSULATION DESIGN PROBLEM

Problems of designing an insulation system for an electromechanical device can be visualized by referring to the hypothetical illustration of Fig. 1, which points up many of the design factors encountered in more complex designs. A coil form insulates the turn of magnet wire from the magnetic circuit (ground). Individual turns are insulated from one another by the magnet wire insulation, typically an enamel in miniature equipment where the excessive bulk of wrapped or extruded insulations preclude their use. Lead wires are soldered to the bared ends of the enamel magnet wire. Joints are protected by sleeving which must fit snugly. Sharp edges or points which may pierce the sleeving should not occur. The lead wire, joints and all, must be fastened firmly in place, which in this example is accomplished by taping the whole wound bobbin. The bobbin is then impregnated in a varnish compound which, when cured, provides a



1 Coil form, which serves as bobbin for the winding and structural support for the terminals.

2 Insulated magnet wire.

3 Insulating tape, holds down wrapped solder connections between magnet wire and lead wire.

4 Impregnation varnish forms protective coating.

5 Leadwire, joins magnet wire coil to terminals.

6 Terminals, rigidly mounted on coil form.

7 Magnetic circuit.

8 Airgap

Fig. 1 Electromagnetic device, incorporates typical insulation features found in more complex devices. Essentially it comprises a coil which when energized causes a flux field in the air-gap of the magnetic circuit. The airgap flux may carry out a variety of functions in specific applications, such as closing a relay, actuating a clutch, etc.

hard protective coating. The final steps are the soldering of the lead wires to the input terminals, and the assembly of the coil to the magnet core.

Consider now the actual design of the device of Fig. 1, and the factors to be considered in the choice of materials. The overall unit must function reliably during the required life and under the duty cycles and environmental conditions of its application. Table I lists the environmental conditions that most influence choice of materials. Note that operating temperature is high on the list with humidity a strong second. Items such as radiation are relatively new problems, being derived from outer space and nuclear radiation applications. The table discusses the influence of each of the individual environments on the insulation system and describes some common mechanisms of failure. Table II lists additional design considerations relevant to the device of Fig. 1 and similar structures.

As a general rule, individual elements of an insulation system should be *compatible*, or able to cooperate effectively to serve the required insulating function. The compatability problem is subtle, for which reason some manufacturers recommend an entire insulation system, including all the necessary items that may be required in typical applications. Incompatibility, at its worst, can lead to a serious degradation in overall insulation life. For example, an impregnation varnish may require a cure cycle at such a high temperature that substantial degradation of low temperature components of the insulation system may occur; or the varnish solvent may attack the magnet wire coating. Because of the increasing importance of compatibility in today's complex and severely strained insulation systems, manufacturers are, more than ever, coming out with compatible systems to meet the different temperature range classifications, see Table III. The designer of miniature magnetic components would do well to specify these compatible systems, at the same time paying special attention to the physical characteristics and available size ranges of the individual materials, which may make them unsuitable for highly miniaturized components. After all, cost is generally not of high importance in miniature devices where relatively small quantities of insulation are employed.

TABLE I. Environmetal Effects on Electrical Insulation

TEMPERATURE
High temperature generally affects, adversely, most of the significant properties of electrical insulation. Mechanical properties deteriorate. Varnishes may show cracks after prolonged exposure. Insulation resistance and breakdown voltage decrease with increasing temperature (see Fig. 2). Life is reduced in exponential fashion with increasing temperature. Even small reductions in maximum temperature, say 10°C, may appreciably improve life.

HUMIDITY
High humidity may appreciably reduce insulation resistance, even to the point of failure. A film of moisture on the surface of a dielectric provides a low-resistance path in parallel with the main dielectric path. Water absorption also impairs the dielectric properties perhaps cutting the cross-section resistance by thousands to one.

ALTITUDE
At high altitude the tendency toward arc-over is increased. The important dielectric properties are inability to sustain an arc, and a smooth non-moisture absorbing surface which minimizes the tendency to form a continuous moisture film. In effect the insulation resistance must have a maximum valve surface component.

VIBRATION AND SHOCK
Vibration and shock may cause cracking of insulation providing a path for future penetration of moisture, or for Corona or arc-over. Vibration and shock are particularly troublesome in conjunction with high temperature where thermal expansion and a weakening of physical properties accentuate the possibility of mechanical damage.

SALT SPRAY
Salt spray result in the building of conducting salt deposits which by-pass the insulation. Salt may hasten further the deterioration of some insulating materials.

TEMPERATURE SHOCK
This may lead to cracking of the insulation, resulting in paths for entrance of moisture. Strains may be set up in encapsulating compounds which can distort the configuration of sensitive magnet circuits, or break fragile wires.

RADIATION
Nuclear radiation, particularly gamma rays and neutrons may cause significant insulation deterioration; particularly when associated with high temperatures, above 150°C. The available literature in this field is still too sparse to provide a compact set of design rules and problems must still be studied on an individual basis.

TABLE II

Insulation Design Factors In Small Electromechanical Components

VOLTAGE ENDURANCE
Solid insulation breaks down at different voltages, depending on the duration of voltage application.

AC vs DC
Because of dielectric heating generated in a-c testing, a-c tests indicate a lower breakdown than obtained with d-c tests, even when the ratio of peak to rms value of the ac is taken into account in making the comparison. Furthermore, the time effect with dc is considerably less than with a-c stress.

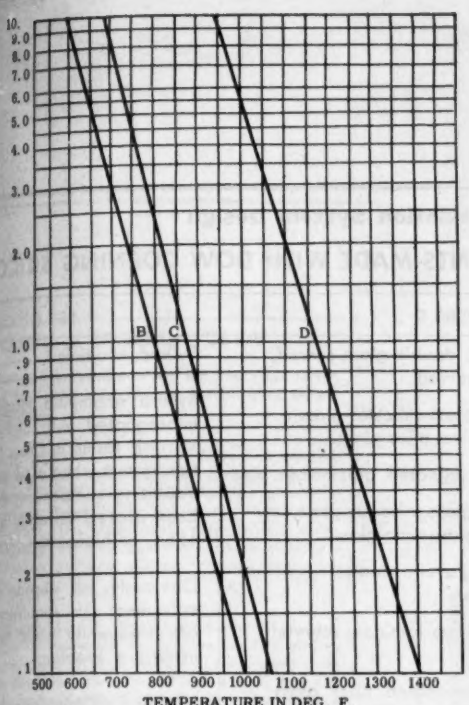
INSULATION SPACING AND CREEPAGE
Humidity and dirt seriously reduce the breakdown level through porous insulation or over a creepage surface. Surface films are usually inhibited in non-porous materials having highly polished surfaces. On such smooth surfaces, moisture tends to settle out as droplets without forming continuous films. Dirt, dust, or microscopic roughness greatly increase the tendency to form a continuous film. Varnish treatment of insulating materials fills the pores and controls moisture penetration. There are a variety of commercially available compounds which may be spread on an insulator surface to inhibit moisture film formation.

DISSIMILAR INSULATIONS
Voltage is distributed across two insulating materials in series directly in proportion to their thicknesses and inversely in proportion to their dielectric constants. When a gaseous and solid insulator are in series, the most usual case, the greater stress occurs across the gas because of its lower dielectric constant, causing it to break down first, transferring full voltage to the solid insulation.

MOISTURE CONTAMINATION
In addition to its deleterious effects on surface leakage, moisture may penetrate the pores of solid insulators, reducing insulation resistance and increasing power factor. Porous materials usually absorb a high volume of moisture, and have surfaces that wet easily.

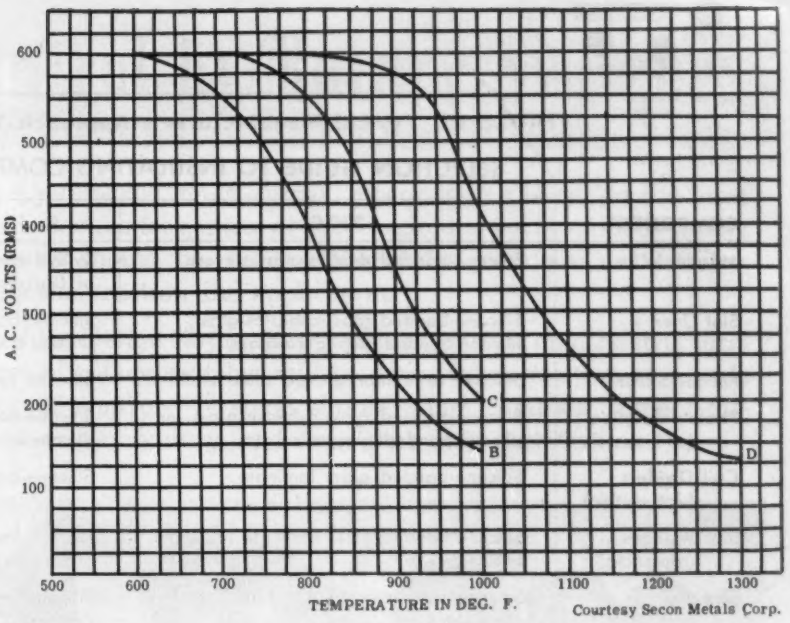
CUT-THROUGH STRENGTH OF WIRE
In winding the coil, lead wire may be brought out from a starting point deep within the coil. As the fine magnet wire is wound on the bobbin, it must not penetrate the lead wire's insulation, even at high temperatures.

MISCELLANEOUS FACTORS
Other questions relate to random versus layer winding, the use of insulation between coil layers, and the manner of impregnation.



Courtesy Secon Metals Corp.

Fig. 2(a). Effect of temperature on insulation resistance of three types of materials. Courtesy Secon Metals Corp.



Courtesy Secon Metals Corp.

Fig. 2(b). Effect of temperature on voltage breakdown of three types of insulation. Courtesy Secon Metals Corp.

INSULATION CHARACTERISTICS

It is important to understand the specific properties of insulation by which materials and systems may be evaluated. Table IV lists the most important properties. Probably the commonest property is *insulation resistance*. Since all insulating materials conduct electricity to some extent, they have a measurable resistance on application of a d-c voltage. Because the resistance values are extremely high, they are markedly influenced by surface and atmospheric conditions, temperature and humidity being particularly influential factors. Fig. 2 shows the effect of temperature on insulation resistance of three types of materials. Surface impurities, such as grease and dirt may affect insulation resistance by providing a low resistance surface conducting path in parallel with the direct path through the insulation material itself. Applied voltage also affects insulation resistance, so a standard voltage must be selected for comparison testing.

Because insulation resistance varies with these external factors, comparative tests must take them into account if an apparently wide divergence of measured values is to be avoided. The ease with which insulation resistance measurements may be made using inexpensive commercial equipment makes them practical as a quality check on production line apparatus to evaluate cleanliness, dryness, freedom from impurities, completeness of processing, and physical imperfections of a damaging nature.

Insulation resistance increases with time upon the application of a d-c potential, changing rapidly at first and assymptomatically approaching a steady state value. Clean dry insulations have a relatively long time constant, whereas wet insulation with parallel conducting surface paths reach steady resistance values at much lower levels much more quickly. Change in insulation resistance with time after voltage is applied is due to dielectric absorption and the sweep of mobile ions to the electrodes, and is primarily a function of the insulation material itself. Dielectric absorption relates to the accumulation of electric charges within the dielectric itself when it is subjected to an electric field. Capacitive charging is an additional effect, the value of capacitance depending upon the overall geometry of dielectric and electrodes. Fig. 3 shows the equivalent parallel representation of a dielectric material with insulation resistance and internal capacitance.

The level of insulation resistance must not be considered as a direct measure of dielectric strength. Insulation resistance necessarily depends both upon the *insulation resistivity* of the material (resistance per unit volume) and on the geometry of the insulation system.

The *dielectric constant* of an insulating material is the ratio of the parallel capacitance of a given configuration of electrodes with the material as the dielectric to the capacitance of the same electrode configuration with a vacuum as the dielectric.

Additional properties of dielectrics are defined in Table V, the definitions being extracted from the ASTM Standards on Electrical Insulating Materials, Oct., 1959 edition.

INSULATION BREAKDOWN

The most important property of an insulating material is its ability to withstand the dielectric stress of the specific application under the required operating conditions. The dielectric breakdown voltage is that value which causes puncture of the insulation. This puncture is believed to occur as a result of an electron avalanche effect which occurs when the electric field gradient reaches a certain limit, see Fig. 4. The dielectric strengths of commercial insulating materials are substantially under the intrinsic strengths of the pure materials. The values are lower for a number of reasons.

- Existence of defects, holes, conducting and foreign particles in commercial insulation;
- Presence of a stress concentration at electrode edges or points where the breakdown can be initiated, because the electric field is much higher than

TABLE III. Typical Manufacturer's Approach To Insulation System Design

SELECTION GUIDE TO INSULATING COMPONENTS MADE WITH DOW CORNING SILICO

COMPONENT	220 C	180 C	155 C
Magnet Wire	Silicone-bonded double-glass served.	Sylkyd enameled, double-glass served, or Dacron-glass served.	Sylkyd enameled.
Slot Liner	Silicone-bonded glass-asbestos-glass, silicone-bonded glass-mica-glass.	Silicone-bonded glass-asbestos-glass, silicone-bonded glass-mica-glass.	Sylkyd enameled magn impregnated with Sylky Varnish forms a Class F tion system when used wit insulating components tha been proved suitable for 155 C or higher temperat
Feeder Sheet	Silicone resin-impregnated glass cloth.	Silicone resin-impregnated glass cloth.	
Phase Insulation (coil noses)	Silicone-bonded glass-asbestos-glass, or silicone-bonded glass-mica-glass.	Silicone-bonded glass-asbestos-glass, or silicone-bonded glass-mica-glass.	
Coil Dividers (slot section)	Silicone-bonded glass laminate.	Silicone-bonded glass laminate.	Obviously, all silicone c ents meet this requireme
Slot Wedges (top sticks)	Silicone-bonded glass laminate (curved or flat sticks).	Silicone-bonded glass laminate (curved or flat sticks).	are frequently used to inventory problems.
Sleeving	Silicone resin-impregnated fiber glass sleeving.	Silicone resin-impregnated fiber glass sleeving. Silastic tubing, Silastic impregnated fiber glass sleeving.	Modified silicones, epoxie mines and other materia be used in Class F sys proved to be capable of tion at 155 C by tests con according to procedures mended in the AIEE publ No. 1.
Lead Wire	Silastic insulated with silicone-bonded fiber glass braid.	Silastic covered, or Silastic insulated with silicone-bonded fiber glass braid.	
Tape	Pressure-senstitive silicone glass-cloth tape.	Pressure-sensitive silicone glass-cloth tape.	
Tying Cord	Silicone-resin impregnated glass or untreated glass sleeving.	Silicone resin-impregnated glass, or Silastic impregnated glass, or untreated glass cord.	
Varnish	Dow Corning 997 Varnish.	Dow Corning 997 Varnish.	Sylkyd 1400 Varnish.
Turn-to-Turn Insulation for Bare Conductors	Silicone varnished glass cloth, silicone-impregnated asbestos paper, or silicone-bonded mica-glass.	Silastic coated or silicone varnished glass cloth.	
Coil Wrapper (tape or sheet)	Varnished glass cloth, silicone-bonded mica or asbestos-glass.	Silastic, Silastic coated glass cloth, silicone-bonded mica or asbestos-glass.	
Barrier Insulation	Silicone glass laminate or silicone-bonded asbestos.	Silicone glass laminate, silicone-bonded asbestos or Silastic coated glass cloth.	
Axial Spacers	Silicone glass laminate, silicone-bonded asbestos, ceramic, or silicone impregnated transite.	Silicone glass laminate, silicone-bonded asbestos, ceramic, or silicone impregnated transite.	

TABLE IV Properties of Insulation

MECHANICAL

1. Tensile strength
2. Tear strength
3. Resistance to abrasion
4. Flexibility
5. Bond strength
6. Resiliency
7. Stability

THERMAL

1. Aging properties
2. Heat transferability
3. Temperature stability
4. Conductivity
5. Expansion and contraction

CHEMICAL

1. Resistance to contaminants and corrosive atmospheres
2. Resistance to gases, oils, moisture, atmospheres and solvents

ELECTRICAL

1. Electric strength
2. Voltage endurance
3. Dielectric loss
4. Dielectric constant
5. Surface resistance
6. Arc resistance
7. Corona resistance
8. Radiation resistance
9. Power factor

Note:

This material extracted from "Functional Life Tests of Apparatus As Compared With Insulation Material Tests", by M. L. Manning, AIEE #59-1293

the average;

- In a-c tests, because of the damaging effect of electric discharge during testing;
- Dielectric heating, which raises the temperature and lowers the breakdown strength.

The following paragraphs from the Westinghouse Engineer, *Physics of Insulation*, by T. W. Dakin, describe these phenomena in more detail.

"The presence of defects lowers the dielectric strength at points in a somewhat random manner and produces a dispersion of test results. Larger areas exposed to voltage have a lower dielectric strength, since it is more probable that they include a few bigger defects.

"Electric stress concentration at edges and points has, in the case of gases, the effect of producing corona, a local breakdown at the edge or point but not a complete breakdown of the gap. However, in the case of small

MATERIALS SELECTION GUIDE

WIRE: Sylkyd enameled wire has best space factor; glass, best mechanical strength; double-glass served, thermal stability.

SHEET INSULATION: For slot liners and coil-nose insulation, wherever mechanical pressure may be used, silicone-bonded glass-asbestos-glass or glass-mica-can be used. Generally, the glass-mica-glass has better resistance; the glass-asbestos-glass is less costly. Under sheets, or wherever maximum flexibility in sections thin as 2 mils is required, silicone varnished glass cloth preferred.

SHEET INSULATION: Silicone-bonded glass laminate preferred for its mechanical strength, low moisture absorption and thermal stability. Coil dividers and slot wedges can be cut from sheet insulation; formed slot wedges are also available. In larger machines, formed slot wedges offer a cost factor advantage. Silicone laminates can be machined or punch-cut to form terminal boards, insulating washers and other structural parts.

SLEEVING: Silicone resin-impregnated fiber glass sleeving has the best thermal stability and mechanical strength. Silastic-impregnated fiber glass sleeving has greater flexibility; Silastic tubing has best flexibility and moisture resistance.

WIRE: Silastic insulated silicone-bonded fiber glass covered wire has best thermal stability and abrasion resistance. Silastic covered wire has greater flexibility.

TYING CORD: Silicone treated tying cord has better handling characteristics; silicone resin-impregnated glass cord has best thermal stability; Silastic impregnated cord, best flexibility and knotting characteristics.

VARNISH: For maximum reliability from systems designed for 200°C or higher, Dow Corning 997 Varnish is recommended. For 155°C or lower temperature systems, Sylkyd 1400 Varnish, a modified silicone, offers superior oil and solvent resistance.

gaps or high pressures in gases, breakdown at a positive point propagates by means of a streamer completely across the gap. In homogeneous solid insulation it is probably not possible to have a partial breakdown at a point without propagating the breakdown completely through the insulation. However, in the case of a composite dielectric such as a solid sheet in mineral oil, the oil can break down at an edge or point, forming corona, without immediately resulting in the solid breakdown.

"The ratio of the electric field strengths in different dielectric materials in series varies inversely as the ratio of their dielectric constants. This effect places a higher electric stress on the low dielectric-constant constituent of a composite insulation. Often this constituent has a lower dielectric strength, which insures that it will break down at a lower voltage. This effect in itself usually lowers the over-

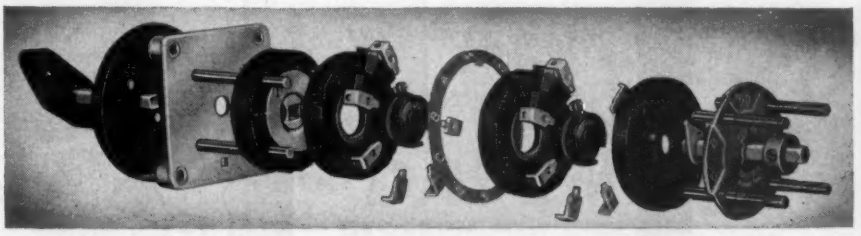
DESIGN NOTES on

Control by Rotary Switches

(No. 1 of a series)

The multi-pole, multi-circuit, rotary switch is one of the most versatile devices for control of electric circuits yet it is not as widely used as it should be, because many designers are not familiar with its construction and application.

In these Design Notes, the operating principle and the structural features of rotary switches will be discussed in relation to a wide variety of controls — some simple, some complex, some light-duty, some heavy-duty, and some that defy classification.

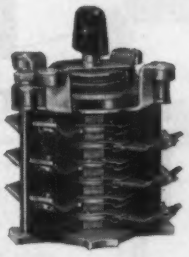


Exploded view of ESCO Type JR — a typical rotary switch.

The type of switch we are talking about does not fit into any clearly defined category. It is called a *rotary switch* because its moving parts rotate on a shaft so that the switch can be operated by turning a knob, handle, or hand-wheel — either manually or by a motor, solenoid, or other form of power drive. Altho the term *rotary switch* is sometimes loosely used to mean any switch that can be operated by turning a shaft (as in the case of a switch having cams that open and close contact circuits), there are important differences that put the true rotary switch in a class by itself for many applications.

Basic Structure of Rotary Switch

The first characteristic to be considered is the physical arrangement of the contacts. In the rotary switch, stationary contacts are distributed radially on an insulating base, generally called a *deck*, or a *section*. Sometimes they are riveted or otherwise secured to the deck but more often they are set in molded recesses. The movable contacts, which are carried on an insulating member keyed to the switch shaft, are free to move slightly so as to align themselves with the stationary contacts. Since the shaft is generally made of metal, insulation adequate to prevent flashover is provided between the movable contacts and the shaft. In some designs, the movable contacts are connected to the external circuit through a slip ring; such switches are generally called tap, or selector switches. For more complex circuit controls, the movable contacts may be used to interconnect two or more stationary terminals.



ESCO Bulletin No. 8A, containing useful information on the construction and application of rotary switches, as well as examples of ESCO switches that utilize the design principles discussed in these advertisements, will be sent you on request.

ESCO of WEYMOUTH

ELECTRO SWITCH CORP.

Weymouth (Boston 88), Massachusetts

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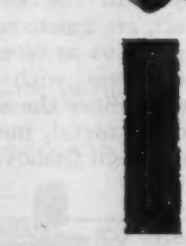

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COMPONENTS DIGEST

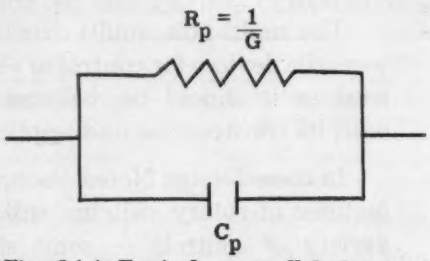

Fig. 3(a) Equivalent parallel circuit of an electrical insulation.

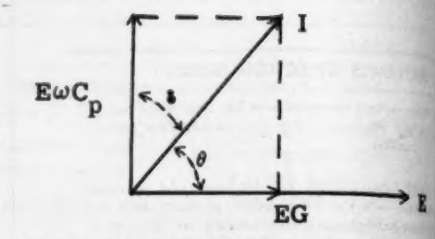

Fig. 3(b) Vector diagram for equivalent parallel circuit.

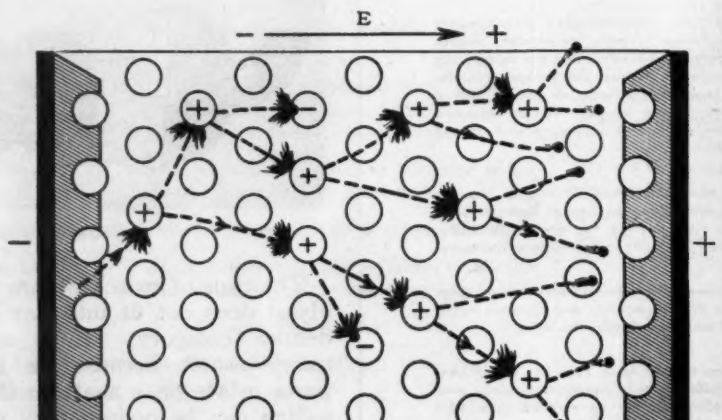

Fig. 4 Pictorial representation of an electron avalanche, which occurs at the beginning of electric breakdown. An initial electron from the cathode, accelerated by the electric field, collides with an atom or molecule, causing secondary electrons to be emitted. These in turn are accelerated and collide with other atoms or molecules. As the number of electrons multiplies, a conducting path develops through the insulating material.

all dielectric strength of the composite insulation, since, when partial breakdown of one part occurs, a higher stress appears on the remainder.

"When corona appears and continues for a time at the surface of insulation under electric stress, it erodes the surface by decomposing the insulation with electron bombardment and the associated heat of the corona discharge. This effect seems to begin immediately and even fraction seconds of exposure at a-c voltages near the breakdown voltage lower the breakdown strength appreciably.

"A consequence of the stress concentration at points and edges is the decrease of the breakdown gradient (volts per mil) of all materials with increasing thickness or spacing. This factor is not generally appreciated in engineering circles, where volts per mil dielectric-strength values are often quoted and compared without reference to the insulation thickness used in determining the values. It is apparent that the electric-field gradient at the point or edge of an electrode decreases less than proportional to the reciprocal of the spacing. In fact, for simpler geometric electrodes, it can be calculated that the gradient near an edge or point decreases as an inverse fractional power of the spacing. Present knowledge indicates that once breakdown begins within a solid at an edge or point it continues through the material. This is contrary to the case of gases at lower pressures and larger spacings, where local breakdown can occur at an edge or point, giving the well-known corona, without completely bridging the gap."

In all solid insulations, the barrier must be continuous and nonporous. The breakdown gradient may vary considerably depending upon the quality

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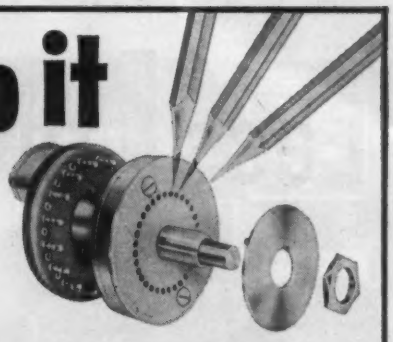

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Daven Rotary Switch with adjustable stop!

For flexibility in circuit experimentation, laboratory work, breadboard setups and circuitry where the exact number of switch positions might be changed at a later date. As a single pole switch, it has a maximum of either 24 shorting positions with 15° spacing or 32 shorting positions with 11¼° spacing. One, two, three and four pole units are available. Write today for complete information.

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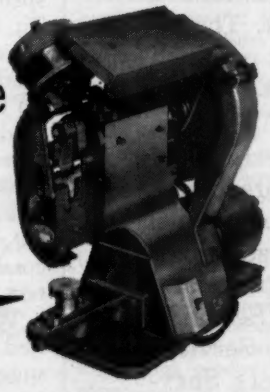
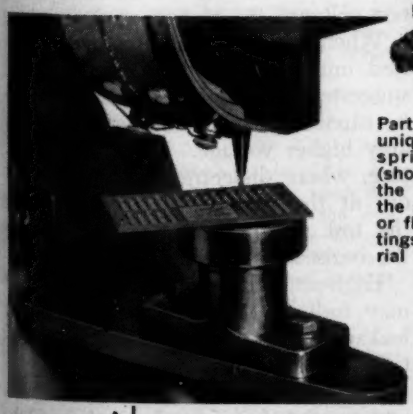
PLANNING FUNNEL TYPE EYELETS FOR PRINTED CIRCUIT BOARDS?

this Edward Segal automatic machine feeds, inserts and flares with utmost reliability!





Part of the secret's in Segal's unique anvil tool holder and spring loaded work table (shown at left) which allow the eyelet to pass through the assembly before staking or flaring. Avoids loose settings, compensates for material variations, too.

There's a Segal machine for every eyeleting application. Tell us about yours and we'll gladly look into it without obligation. And write today for new bulletin EMD-5.

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Manufacturers of eyeleting machinery, special hoppers and feeding devices
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push-pull CONTROLS

Compression & Tension Type

Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¼" minimum bend radius.

Three Types:

1. *Light Duty*—Compression Ult. Load 1250 lbs.; Ult. tension 960 lbs.
2. *Heavy Duty*—Compression Ult. Load 1650 lbs.; Ult. tension 960 lbs.
3. *Extra Heavy Duty*—Compression Ult. Load 3050 lbs.; Ult. tension 3900 lbs.

Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys, and dual cables. U.S. Patent No. 2441719. All world rights reserved. Send for ENGINEERING MANUAL giving complete specifications covering materials, finishes, capacities. Please address Dept. EMD-PP-60.

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Less than .005" Runout on a 24" Shaft...

Holtzer-Cabot Solves Fractional H.P. Motor Problems

Holding runout tolerances on a motor shaft extending 24" beyond the motor frame poses a difficult design problem. To reduce runout, many manufacturers have resorted to complicated and expensive outboard bearings and shaft supports. To avoid this problem, one such company* came to Holtzer-Cabot, which in cooperation with the company's engineers, developed a motor with a special extended end cap and a heavier shaft. The result: less than .005 runout at one inch from the end of the 24" shaft.

Write for Information! Holtzer-Cabot specializes in the design and manufacture of fractional horsepower motors for all types of applications. For complete details on Holtzer-Cabot motors for specific applications, and a copy of "Key Factors in Selecting AC Motors for Instrument Service" write direct or use Readers Service Card.

**Name on request*

HOLTZER-CABOT
MOTOR DIVISION
National Pneumatic Co., Inc., Boston 19, Mass.

CIRCLE NO. 69 ON INQUIRY CARD

COMPONENTS DIGEST

and uniformity of the insulation and its manner of fabrication. The dielectric barrier must be maintained in the presence of contaminants such as dirt and moisture. When corona occurs at the surface between a solid and gaseous insulation, the voltage across the gas space drops sharply putting full voltage across the solid insulation. Corona may occur between closely spaced electrical terminals, particularly at high altitudes. Silicone insulations are highly resistant to the oxidizing agents generated as by-products of Corona.

HI-POT TESTING

Probably the most commonly used dielectric test performed on high production electrical devices is the a-c high-potential (or hi-pot) test. This test and the d-c insulation resistance test comprise most of the production insulation tests carried on today.

The a-c high-potential test is performed by applying an alternating voltage between members which should be insulated. These may be the separate windings of an electrical resolver, or the windings and frame of a transformer. The test voltage is substantially higher than the normal voltages encountered in use, and is applied for a specified period, typically one minute. To avoid voltage transients which exhibit sharp spikes, voltage is increased gradually at a prescribed rate. To speed up testing, an overvoltage test with immediate application of full voltage for several seconds may be substituted. Because these tests tend to deteriorate insulation, repeat tests, after final checkout by the manufacturer are generally conducted at 80% of the manufacturer's test voltage.

When high-potential testing is carried out on finished equipment, it is suggested that individual components be capable of withstanding a considerably higher voltage. During manufacture, where dielectric tests are carried out at the various production stages, the test voltages must be selected on the basis of experience.

High-potential a-c dielectric tests may indicate breakdown or excessive leakage. Unfortunately, test specifications do not define dielectric failure in a precise manner. The amount of leakage current, for example, varies widely for different units and must be specified on the basis of production experience. Leakage current is measured conveniently by the glow of a neon

TABLE V

Additional Definitions Relating To Insulation Resistance

Capacitance—The capacitance, C, of a capacitor is the ratio of the charge which can be stored in the capacitor to the potential applied to it. It is expressed in farads when the charge is expressed in coulombs and the potential in volts.

Dielectric Constant—The dielectric constant, K, of an insulating material is the ratio of the parallel capacitance (Fig. 3) of a given configuration of electrodes with the material as the dielectric to the capacitance of the same electrode configuration with a vacuum as the dielectric.

Dissipation Factor—The dissipation factor of an insulating material is the ratio of the conductance, G, of a capacitor in which the material is the dielectric to its susceptance, B, or the ratio of its parallel reactance, X_p, to its parallel resistance, R_p, (Fig. 3). It is also the tangent of the loss angle, tan δ (also called loss tangent), and the cotangent of the phase angle, cot θ. It is represented by the symbol D:

$$D = \cot\theta = \tan\delta = G/B = X_p/R_p = G/\omega C_p = 1/R_p\omega C_p$$

where:

$\omega = 2\pi$ times the frequency in cycles per second.

The reciprocal of the dissipation factor, D, is the storage factor, Q, sometimes called the quality factor.

Loss Factor—The loss factor, DK, of an insulating material is equal to the product of its dissipation factor, D, and dielectric constant, K. It is proportional to the energy loss per cycle per squared potential gradient per unit volume.

Power Factor—The power factor of an insulating material is the ratio of the power in watts dissipated in a capacitor in which the material is the dielectric to the product of the sinusoidal voltage and current expressed in effective volt-amperes. It is also the cosine of the phase angle of the material, cos θ, and the sine of the loss angle, sine δ. It is usually represented by the symbol PF.

Note: when the dissipation factor is less than 0.1, the power factor is smaller than the dissipation factor by less than 0.5 per cent. Their exact relationship may be found either by reference to trigonometric tables or from the following relations:

$$PF = D/(1+D^2)^{1/2}$$
$$D = PF/[1-(PF)^2]^{1/2}$$

Phase Angle—The phase angle of an insulating material is the angle by which the current in a capacitor, in which the material is the dielectric, leads the voltage across it, as shown in Fig. 3, both current and voltage having the same frequency. It is represented by the symbol θ.

Loss Angle—The loss angle of an insulating material is the complement of its phase angle. It is represented by the symbol δ. It is sometimes called the phase defect angle.

Series Representation—While the parallel representation of an insulating material having a dielectric loss is fundamental, it is always possible and occasionally desirable to represent a capacitor at a single frequency by a capacitance, C_s, in series with a resistance, R_s. The dissipation factor, D, of the capacitor is the same for both the series and parallel circuits as follows:

$$D = R_s\omega C_s = 1/R_p\omega C_p$$

The relations between series and parallel components are as follows:

$$C_s/C_p = 1+D^2$$
$$R_p/R_s = (1+D^2)/D^2 = 1+1/D^2 = 1+Q^2$$

Note: the series capacitance is larger than the parallel capacitance by less than 1 percent for a dissipation factor of 0.1, and by less than 0.1 percent for a dissipation factor of 0.03.

If the measuring circuit yields results in terms of series components, the parallel capacitance must be calculated before determining the dielectric constant.

SIGNIFICANCE

Dielectric Constant—Insulating materials are used in general in two distinct ways, (1) to insulate and support components of an electrical network from each other and from ground, and (2) to function as the dielectric of a capacitor. For the first use, it is generally desirable to have the capacitance of the support as small as possible, consistent with acceptable mechanical, chemical, and heat-resisting properties. A low value of dielectric constant is usually desirable, so that the capacitor may be physically as small as possible. Intermediate values of dielectric constant are frequently used for grading stresses at the edge or end of a conductor to minimize corona.

Power Loss—For both cases (as electrical insulation and as capacitor dielectric) the power loss generally should be small, both in order to reduce the heating of the material and to minimize its effect on the rest of the network. A low value of loss factor, at high frequencies is desirable because, for a given value of loss factor, the power loss increases directly with frequency. In certain dielectric configurations such as are used in bushings and cables, an increased loss, usually obtained from increased conductivity, is sometimes introduced to control the voltage gradient in the insulation. In comparisons of materials having approximately the same dielectric constant, the quantity considered may also be dissipation factor, power factor, phase angle, or loss angle.

Correlation — When adequate correlating data are available, dissipation factor or power factor may be used to indicate the suitability of a material in other respects, such as dielectric breakdown, moisture content, degree of cure, and deterioration from whatever cause. While the actual value of dissipation factor is important initially for any material, it is the change in dissipation factor that is significant when there is a change in the material.

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ELECTROHYDRAULIC SERVO VALVE

Kearfott's unique approach to electrohydraulic feedback amplification design has resulted in a high-performance miniature servo valve with just two moving parts. Ideally suited to missile, aircraft and industrial applications, these anti-clogging, 2-stage, 4-way selector valves provide high frequency response and proved reliability even with highly contaminated fluids and under conditions of extreme temperature.

TYPICAL CHARACTERISTICS

Quiescent Flow ..... 0.15 gpm
Hysteresis .. 3% of rated current
Frequency Response 3 db @ 100 cps
Supply pressure....500 to 3000 psi
Temperature-Fluid & Ambient —65° F to +275° F
Flow Rate Range .... .3 to 10 gpm
Weight ..... 10.5 ounces

Write for complete data.

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

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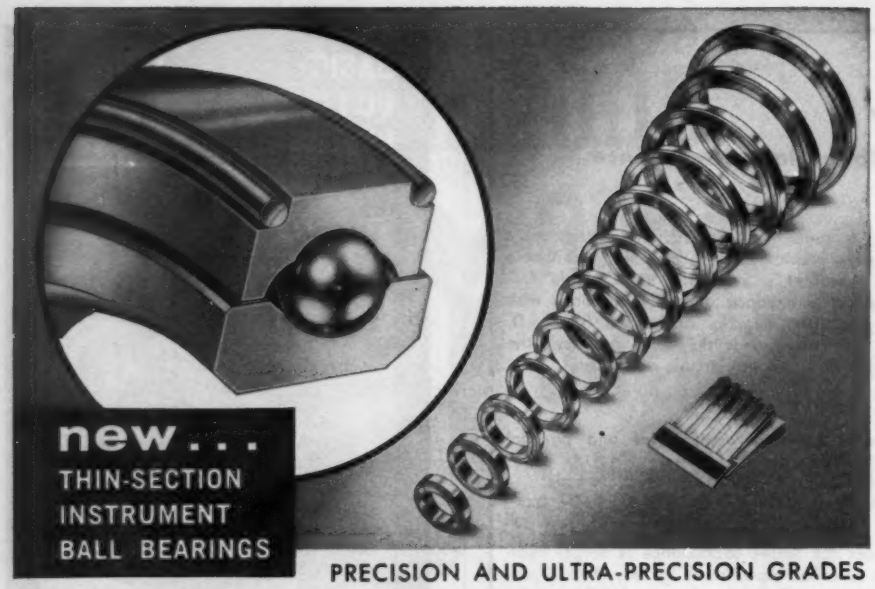

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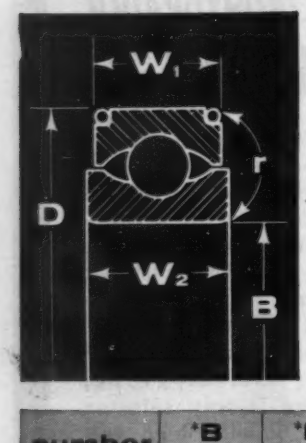
TYPE TWF WITH INTEGRAL SHIELDS



A thin-section radial ball bearing with integral shields on both sides. Deep groove ball races with continuous shoulders, uninterrupted by filling slots. Maximum radial and thrust capacity possible in a radial ball bearing of its dimensions. The close-clearance annulus between shields and inner ring fills with lubricant and functions as an effective seal without the objectionable torque found with contact seals. This design in a precision instrument bearing is possible only with the Split Ballbearing method of construction. Also made in type TWA with alternate balls slightly undersize, for lower torque applications.

Balls and rings are 52100 high chrome alloy bearing steel. Also available in 440 C stainless.

number	*B bore	*D o.d.	W_1 +.000 −.005	W_2 +.000 −.005	Balls no.	Balls size	wt. lbs.	‡L lbs.	§S lbs.
TWF 10-17	.6250	1.0625	.250	.281	24	7/64	.042	276	500
TWF 12-19	.7500	1.1875	.250	.281	24	1/8	.047	354	650
TWF 14-21	.8750	1.3125	.250	.281	27	1/8	.052	375	730
TWF 17-24	1.0625	1.5000	.250	.281	32	1/8	.06	435	870
TWF 21-28	1.3125	1.7500	.250	.281	38	1/8	.07	440	1030
TWF 25-32	1.5625	2.0000	.250	.281	44	1/8	.08	470	1200
TWF 29-36	1.8125	2.2500	.250	.281	50	1/8	.09	490	1360
TWF 33-42	2.0625	2.6250	.250	.281	58	1/8	.14	520	1580
TWF 37-46	2.3125	2.8750	.250	.281	64	1/8	.16	545	1740
TWF 41-52	2.5625	3.2500	.312	.375	48	3/16	.24	1010	2900
TWF 45-56	2.8125	3.5000	.312	.375	52	3/16	.28	1040	3150
TWF 49-62	3.0625	3.8750	.312	.375	58	3/16	.32	1100	3500

Dimensions are in inches. Radius "r" will clear .015" shaft or housing fillet. *Tolerances vary according to size — see catalog 59 for Precision Grade and Ultra-Precision Grade Tolerances. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-brinell load capacity.

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Split's catalog 59 provides complete coverage on the complete T series of thin-section precision instrument ball bearings. No designer should be without it.

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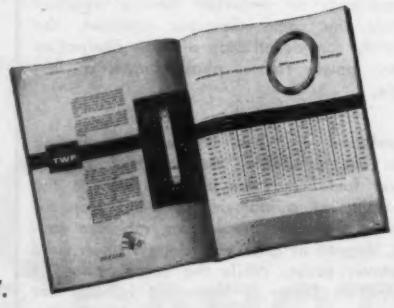

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CIRCLE NO. 71 ON INQUIRY CARD

COMPONENTS DIGEST

bulb across a resistor in series with the dielectric circuit. The resistor must be reduced for components whose large size or insulation characteristics results in high but tolerable leakage. Capacitance between windings and magnetic circuit, where the insulation acts as a dielectric, as well as capacitive currents flowing in the dielectric itself contribute to the so-called leakage current.

A similar neon bulb across a series choke registers breakdown. Any arcing results in the generation of r-f currents and a consequent build up of voltage across the choke. This bulb indicates breakdown, arcing, or corona.

High-potential testers frequently are designed with high output impedance to limit the glow of damaging currents under breakdown. Sensitive circuit breakers may provide similar protective action.

SELECTION OF SPECIFIC INSULATIONS

Choosing the best insulations for a given job is a very difficult task. The list of available types in every class is enormous. We have, therefore, avoided classifying commercially available insulations but rather have concentrated on describing insulation characteristics, design factors, and methods of test. Our aim has been to acquaint the project engineer with the fundamentals which permit him to read about and discuss insulations with some understanding. In the last analysis the principal information is obtained directly from the insulation manufacturer.

Electromechanical designers should recognize *all* the important factors affecting the performance of a given insulating material. In a search for a reliable, high-temperature slot liner, for example, they ought not overlook mechanical properties such as brittleness which precludes its use in miniature machines. When the insulator is used to support structural loads its tensile strength may be important. Potting compounds may shrink while hardening, setting up internal stresses which may break fragile windings. Thus, the more complete the knowledge of significant parameters and their measurement, the surer will be the choice of insulation. And overall, there is the all inclusive requirement of compatibility.

As an aid to the project engineer who deals to a significant degree with electrical insulation, the ASTM publishes Standards on Electrical Insulating Materials. This collection covers

TABLE VI

Scope of Topics Covered in ASTM Compilation of Standards on Insulation Resistance

Insulating Shellac and Varnish	Insulating Papers
Effects of Radiation	Mica Products
Plates, Sheets, Tubes, Rods and Molded Materials	Magnet Wire Insulation
	Plastics for Electrical Insulation
Ceramic Products (Glass, Porcelain, Steatite)	Rubber Tape and Electrical Protective Equip-
Solid Filling, Treating, Encapsulating, and	ment
Embedding Compounds	Textile Materials for Electrical Insulation
Flexible Sheet, Tape, and Tubing	General Test Methods

TABLE VII

More ASTM Definitions Relating To Insulation Resistance

Insulation Resistance—The insulation resistance between two electrodes which are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to the total current between them. It is dependent upon both the volume and surface resistances of the specimen.

Volume Resistance—The volume resistance between two electrodes which are in contact with, or embedded in, a specimen is the ratio of the direct voltage applied to the electrodes to that portion of the current between them that it distributed through the volume of the specimen.

Surface Resistance—The surface resistance between two electrodes which are on the surface of a specimen is the ratio of the direct voltage applied to the electrodes to that portion of the current between them which is in a thin layer of moisture or other semiconducting material that may be deposited on the surface.

Volume Resistivity—The volume resistivity of a material is the ratio of the potential gradient parallel to the current in the material to the current density.

Surface Resistivity—The surface resistivity of a material is the ratio of the potential gradient parallel to the current along its surface to the current per unit width of surface.
Note: surface resistivity of a material is numerically equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square is immaterial.

SIGNIFICANCE

Insulation Resistance — Insulating materials are used in general to insulate and support components of an electric network from each other and from ground. For this purpose it is generally desirable to have the insulation resistance as high as possible, consistent with acceptable mechanical, chemical, and heat-resisting properties, although in many cases it need be only high enough to have no appreciable effect on the operation of the network. Since insulation resistance combines both volume and surface resistance, its measured value is strictly applicable only when the test specimen has the same form as is required in actual use.

Volume and Surface Resistivity—When the volume and surface resistivities of an insulating material have been determined, it becomes possible to design an insulator for a specific application. The changes of both resistivities with temperature and humidity may be great, and must be known in order to meet operating conditions. Surface resistivity changes very rapidly with humidity, while volume resistivity changes only slowly, although the final change may be greater. Volume and surface resistivity measurements are often used in checking the uniformity of an insulating material, either to determine the uniformity of processing or to detect traces of impurities which affect the quality of the material and which may not be readily detectable by other methods.

Correlation — When adequate correlating data are available, resistance or resistivity may be used to indicate the suitability of a material in other respects, such as dielectric breakdown, dissipation factor, moisture content, degree of cure, mechanical continuity, and deterioration from whatever cause. While the actual value of resistance or resistivity may be important initially for any material, it is the change in resistance or resistivity that is significant when there is a change in the material. The insulation resistance test is of greatest value when the test specimen has the same form as that required in actual use.

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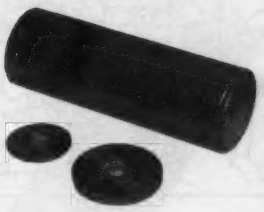

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Peak Magnetic Field Strength	1200 gauss
Period	0.560 in.
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Inside Diameter of Pole Pieces	0.400 in.
Outside Diameter	2.0 in.
Weight	3.2 pounds

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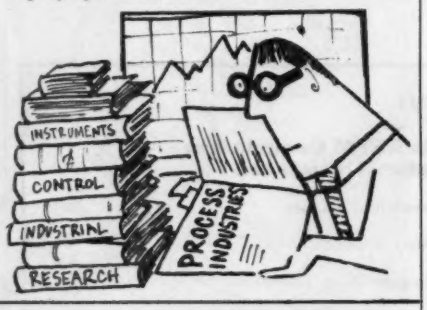

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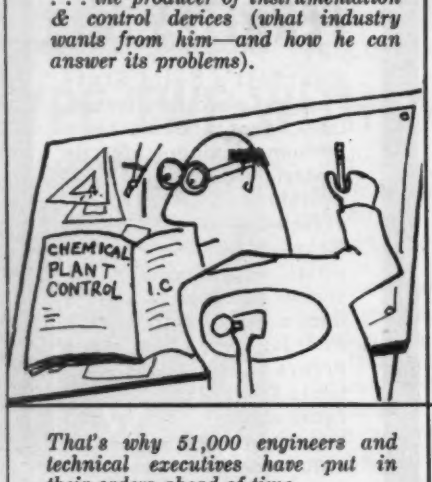

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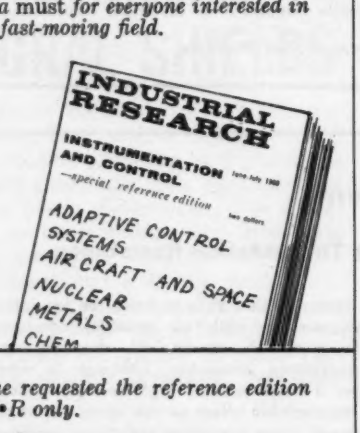

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COMPONENTS DIGEST

definitions, test procedures and discussion relating to the broad categories of Table VI. Engineers interested in these categories would do well to become familiar with this material prior to serious study of specific insulations. These standards are constantly being up-dated by Committee D-9 of the American Society for Testing Materials. Tables VII through IX contain excerpts from this material, both as an introduction to the Standards, and as useful information in its own right.

There are other groups dealing more or less with insulation, including such prominent organizations as NEMA, ASA, JIC, and the AIEE. The latter organization is particularly active in defining insulation standards by temperature, see Components Digest 10, Dec., 1959, on high temperature materials, and on test methods particularly applicable to the insulation of electric motors and power machinery.

In the field of new developments, principle progress has been in the area of equipment miniaturization, higher temperatures, and unusual environments such as in outer space, or in the vicinity of nuclear radiation. The effects of nuclear radiation may, indeed, be quite startling, affecting insulations as well as other components in unexpected manner. Where high temperatures, nuclear radiation, and a long life requirement occur simultaneously as in nuclear reactor controls, the problems become quite severe. Data in this field is still quite scarce, and much remains to be accumulated. Some of the important facts are that high temperature insulations generally suffer less from radiation than lower temperature insulations, that inorganic materials do better than organics, that ceramics do well, while Teflon does not, and Silicones do moderately well. For some satellite applications, much remains to be learned about outer space environments. ASTM specifications D1671-59T and D1672-59T consider effects of radiation.

Components Digest 10 of Dec., 1959, pays special attention to advanced problems in insulation. Future Digests will cover specialized areas of this important and growing field.

CONFERENCE ON APPLICATIONS

This section summarizes those papers presented at the Second Annual National Conference on the Application of Electrical Insulation—1959 that are

TABLE VIII

Insulation Properties Covered in ASTM D-48-57T, "Tentative Methods Testing Molded Materials Used for Electrical Insulation."

Arc Resistance—The ability of a material to withstand the discharge across its surface of a specified, at first intermittent and then continuous, high-voltage, low-current arc. Materials may fail through the eventual formation of a conducting path across their surfaces, and must then be judged for arc resistance by their probable ability to withstand some lesser amount of arcing, thought to be the maximum to which they are likely to be exposed.

Dielectric Constant—The ratio of the capacitance of a capacitor in which the material tested is the dielectric to the capacitance of the same capacitor with vacuum (or air) as the dielectric. Test values obtained are a measure of the relative capacity of a material to store electrostatic energy.

Power Factor—The ratio of that part of the current which produces heat in the dielectric to total alternating current which passes through the dielectric.

Loss Factor—The relative tendency of a material to generate heat when used as a dielectric in an electrical field alternating at a specific frequency.

Dielectric Strength—The voltage gradient at which a material fails as a dielectric by electrical breakdown.

Insulation Resistance—The resistance offered by a specimen to the passage of direct current between electrodes attached to it.

Volume Resistance—The resistance offered by a material to the passage of direct current if passage of current through or over its surface layer is prevented.

Compressive Strength—The ability of a material to withstand compressive loads without complete failure.

Flexural Strength—The ability of a material to withstand bending loads without complete failure.

Impact Strength—The ability of a material to withstand a sudden blow without complete failure.

Tensile Strength—The ability of a material to withstand tensile loads without complete failure.

of most significance to the electromechanical designer.

H. L. Saums, E. H. Olson, W. W. Pendleton of Anaconda Wire and Cable Company report in AIEE CP#5054 on the present status of "Epoxy Enameled Magnet Wires." This Class B (130° C) insulation is compatible with the usual commercially available insulations, most impregnating varnishes and compounds. Epoxy resins exhibit exceptional chemical stability, being undamaged by strong alkaline solutions at relatively high temperatures.

In "Progress in High Temperature Applications of Epoxy Resin Insulation", AIEE CP#5035, John Delmonte of Furane Plastics Co. states that newer epoxy resin insulating materials and curing agents have demonstrated long-time thermal stability at temperatures up to 400° F., representing a decided advance in performance ratings. Much higher temperatures are feasible for short time intervals, such as in missiles and rockets.

"Progress in Silicone Insulation", AIEE CP#5097, is the topic of J. S. Hurley, Jr., of General Electric Co., reporting on all the basic lines, including silicone fluids, silicone resins, and sili-

TABLE IX

ASTM Specification Relating to Classification of Impregnation Varnishes

Control—The following tests are useful for control purposes during the manufacture and use of varnishes, and for determining the uniformity of batches:
(1) Specific gravity,
(2) Viscosity,
(3) Flash point, and
(4) Nonvolatile matter by weight.

Performance—The following tests are useful for determining the performance of varnishes during application and use:
(1) Draining (working viscosity),
(2) Time of drying,
(3) Dielectric strength,
(4) Heat flexibility, and
(5) Oil resistance.

CLASSIFICATION AND DEFINITIONS

Alcohol-soluble Varnishes—Clear or colored varnishes that form films, primarily by evaporation of solvents, and that are intended for application to electrical apparatus that may be exposed to mineral oils or related materials.

Oxidizing Air-Drying Varnishes—Clear or colored varnishes that form films at room temperatures, primarily by oxidation.

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Linearity at 0-3600 rpm	.07
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cone elastomers as well as modifications of these products which fit into electrical applications. Silicone resins have been known for their excellent electrical properties, but they have lacked in physical properties and ease of handling. The real advances have been improvements in handling properties. Outstanding among the new developments are the new low temperature curing resins, cured at 100° C to 150° C with far superior properties.

Solventless silicone thermosetting varnishes are available for impregnating, encapsulating and potting of electrical devices.

Progress in silicone elastomers can be measured in terms of improved physical properties, more reliable data, and more varieties of compounds to fit existing needs. By optimizing moisture resistance and heat resistance with improved physical properties, a superior insulation has been developed for the manufacture of motors and transformers as well as wire and cable.

Important developments include silicone rubber with the same shrinkage as organic rubbers, low compression set compounds which do not require toxic additives, and new high strength rubbers. A series of compounds is capable of room temperature vulcanizing.

In "Selection of Thermosetting Plastic Systems for Cast Electrical Insulation", AIEE CP#5041, Sid Street of Reichhold Chemicals Corp., lists the special advantages of cast insulations:

- Provide a neater appearance
- May provide savings in material due to high power dissipation capacity
- Protect delicate equipment from amateur adjustments

The most important handling characteristics of casting resins are:

- resin stability (uncatalyzed)
- pot life or gel time (catalyzed)
- curing time
- curing temperature
- viscosity

The most widely used plastics for cast electrical insulation are phenolics, polyesters, and epoxies, which Mr. Street compares in detail. Once the approximate plastic has been selected, inorganic or inert fillers are selected which:

- Reduce shrinkage
- Reduce exotherm by absorbing heat given off during the cure
- Provide a thermal coefficient of expansion more nearly equal to that of the metal conductors, hence, better resistance to thermal shocks.
- Reduce stresses set up during resin polymerization
- In general, reduce the cost of the system.

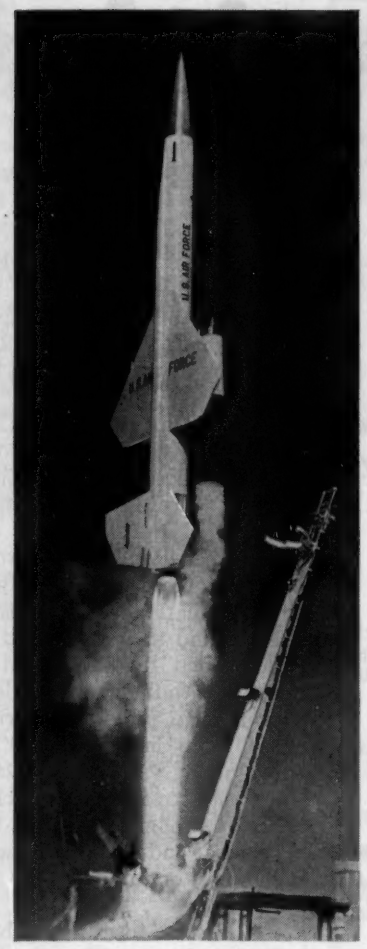
Mr. M. L. Manning, of South Dakota State College, in "Functional Life Tests of Apparatus as Compared with Insulation Material Tests", AIEE#50-1293, weighs the advantages and disadvantages of tests on materials alone versus functional or prototype apparatus testing. He emphasizes that insulations should be classified as systems as well as materials. Mr. Manning describes the insulation system philosophy, the organizational procedure for developing insulations and systems, and the important insulation properties. He further reviews AIEE work in this area, concluding his presentation with an extensive list of references.

R. E. Kincaid, Dow Corning Corp., in AIEE CP#5050, "A New Fast Curing Silicone Varnish" informs us that a fast curing silicone electrical impregnating varnish is now available. Thermal life tests as well as functional insulation system tests indicate that this material can be rated as a Class 180C and 220C varnish. Yet, since this varnish cures at low temperatures, there is no thermal deterioration of organic insulating materials. This new silicone varnish can thus be considered a universal impregnant.

The subject of compatibility is also considered by Henry Lee of Epoxylite Corp., in "Compatibility of Magnet Wire Insulations and Epoxy Encapsulating Resins, AIEE CP#5080. On the basis of many wires and compounds tested to date, and in addition to field experience, he concludes that:

- The AIEE twisted pair specimen, encapsulated in a test tube, provides a reasonable test specimen for compatibility work.
- Epoxy resins and curing agent combinations vary widely in their compatibility with each type of wire,
- Some wires appear to be attacked by the very formulation which reinforces several other wires,
- The situation, unfortunately, requires that each compound be actually checked with each proposed wire.

In "Testing and Evaluating Electrical Insulation for Use in Rotating Electrical Machinery," AIEE CP#5098, Mr. Harold V. Howe of Continental Diamond Fibre Corp. briefly covers the general quality control testing which NEMA and ASTM have set up over the years to control the quality of



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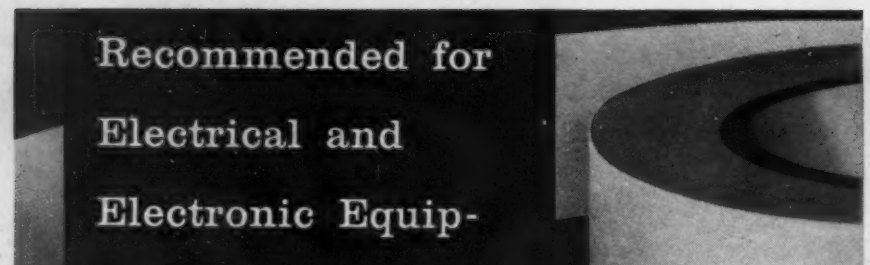

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insulating materials used in rotating electrical machinery. He considers specifically laminated thermosetting products, vulcanized fiber products, varnished products including tapes, strips and wrappers, and silicone products.

J. F. Dexter of Dow Corning Corp., in AIEE CP#5079 discusses the factors in "Evaluation of Electrical Insulating Varnish." In addition to a summary of the functions of insulating varnishes, Mr. Dexter provides an extensive table of "Properties of Electrical Insulating Varnish" listing 27 properties and their associated test methods developed by AIEE and ASTM, and listed in military and federal specifications. He provides a brief review of the more important test methods for evaluating varnish including items such as bond strength, curing characteristics, bond strength at high temperatures, solvent and oil resistance, adhesion, thermal endurance and radiation resistance.

Graham Moses and John C. Botts of Westinghouse Electric Corp., AIEE CP#5073, in "The Significance of Electric Strength of Rotating Machine Insulation" reemphasize that electric strength is the most significant insulation characteristic for large electric machinery. The insulation must be able to support the normal and abnormal voltages encountered during several decades of service. *Voltage endurance* is the ability of insulation to successfully withstand prolonged electric stress. Arbitrary short time dielectric tests are not necessarily suitable for new and untried materials.

"A survey of the Recent Developments in High Temperature Electrical Insulation for Rotating Equipment", AIEE CP#5065, by Jack T. Wilson and Jack C. Davis of Louis Allis Co., points out that the high temperature environments and corrosive atmospheres in which some electrical components must operate indicate material and design problems of a high order of magnitude. These new applications require electrical equipment capable of operating at ambient temperatures of 800 degrees F and higher. The survey describes a completely inorganic insulation system which is evaluated in several integral horsepower motors at the Louis Allis Company over several thousand hours at 800 degrees F with very slight electrical deterioration. The authors conclude that little special el-

fort is required for handling and processing these inorganic insulations, that thermal stability is good to 1000 degrees F and the system is inert under neutron bombardment. However, the insulation does not yet meet the stringent requirements for military apparatus in respect to vibration, shock and moisture resistance.

J. E. Rogers of the Silicones Div. of Union Carbide Corp., brings us up to date on "Developments in Silicone Rubber for Application in Insulation Systems," AIEE CP#5095. He points out that over the past few years silicone rubber has been gaining wide acceptance as a coil-to-ground insulation for form-wound coils of large rotating machines. Its features include:

- excellent electrical properties
- resistance to moisture, chemical attack and weathering
- ability to absorb mechanical shock
- excellent thermal stability.

Properties and recent advances in the use of silicone rubber are described.

"Thermal Stability of Epoxy Encapsulated Magnet Wire", AIEE CP #5068 by E. W. Daszewski, Essex Wire Corp., also covers the subject of insulation compatibility. The conclusions reached by the author are:

- Compatibility does not appear to be a problem with polyvinyl formal wire since thermal life is not reduced by encapsulation in any of the six epoxy compounds investigated. With nyform, epoxy, acrylic, and oleoresinous wire, reduced life can result from use of an improper encapsulant. Life of encapsulated modified polyester is lower than the untreated wire in all six systems.
- Optimum thermal stability for a specific wire depends upon the epoxy encapsulant and is obtained only through a careful selection of the compound.
- Optimum thermal stability for a system depends on the selection of both the wire and the compound.

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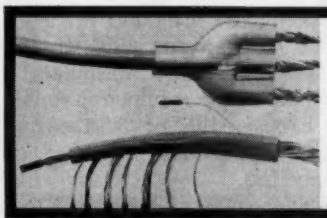

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COMPONENTS DIGEST

New Insulations For Electromechanical Designs

The general nature of this Digest does not permit integration of product information. Such information submitted from manufacturers is included here as a useful addendum.

Bonded Mica

In our December, 1959 issue (p. 58) we reported that design engineers have paid insufficient attention to the possibilities of applying inorganic insulators as structural components in electromechanical assemblies. For example, bonded mica—combining high mechanical strength, high dielectric strength, high durability and moisture resistance, low weight, resistance to oils and organic solvents, low thermal conductivity and high stability—is currently used in the manufacture of disks, slot liners, field coil insulators, small stampings, commutator end rings, channels and troughs. However, for most of these applications, the bonded mica is essentially applied for its excellent electrical insulation characteristics. Many areas possibly exist in which assemblies can be reduced in cost by replacing two or more parts with one made of an insulator that performs mechanical and structural functions as well as insulation functions.

However, information regarding mechanical properties of bonded mica has not been easy to obtain. For this reason we asked New England Mica Co. of Waltham, Mass. to run some strength tests on several of their formulations. Here are some of the results determined by Prof. Ernest Mills of Northeastern University's Department of Mechanical Engineering.

Prof. Mills tested three of New England Mica's formulations; an organic bonded mica, a molding plate mica, and a commutator segment plate mica. The results varied somewhat over a number of tests because of the nonhomogeneity inherent in formulations based on built up mica plates. Ultimate tensile strengths averaged, for the three formulations, from 8700 to 13,400 psi. Consequently, Prof. Mills recommended tensile strengths of 5000, 7500, and 9000 psi as the safe minimum. Because of the negligible deformation of these materials, percent elongation and percent reduction in area have no meaning. Modulus of resilience values averaged about two inch pounds per cubic inch indicating low ability to absorb energy under static loading. Failure does not occur in the clean manner usually associated with brittle materials, but in a laminar fashion.

Normally, bonded mica formulations are not recommended for flexure applications; however, some manufacturers do offer special formulations for applications in which formed parts must withstand bending stresses. Before selecting or designing such parts, check back with the source of supply for recommended formulas and safe working stresses upon which to base your design. New England Mica's molding plate formulations indicated that modulus of rupture values can be had with minimum working stresses varying from 18,000 to 30,000 psi and associated yield strengths varying from 12,000 to 25,000 psi. Modulus of elasticity in bending varied from 8.0×10^6 psi to 10.0×10^6 psi. These values were fairly constant, irrespective of the direction in which the test specimen was cut from the bonded plate. Tests were run as a simple beam with center point loading perpendicular to the flat side of the bonded plate. Because of possible size effects, designs should be checked out with the mica supplier.

Shear tests perpendicular to the surface of the plate yielded essentially similar results for all three formulations and averaged from 12,000 to 15,000 psi. Test-plate thicknesses varied from 0.2 to 0.25 inches.

Fiber Resins

Synthetic fibers in combination with compatible plastics resins produce a flexible chemical and temperature resistant insulation that is not bulky and provides good protection. Designated Duroid 2100 insulation is intended for hermetic applications where resistance to freon-oil mixture is a requirement. Rogers Corp., Rogers, Conn.

Write No. 387 in Box on Inquiry Card

Thermocouple Insulation

Ceramic insulators for thermocouples used in temperatures up to 3200°F are now available in lengths as long as 48". Extruded from a 96% alumina composition, the tubing has a silica content of 1% or less. O.D. size range is from .040 to 1" with single or double holes as small as .015". Saxonburg Ceramics, Inc., Saxonburg, Pa.

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Insulating Varnish

A new silicone base varnish developed especially for use as a protective coating for electronic components, reduces

moisture absorption, protects against electrical leakage caused by contaminants and provides additional protection against breakdown at high altitudes. Maximum recommended operating temperature is well in excess of 400 F. Melpar, Inc. Falls Church, Va.

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Parchment Paper For Coils

New insulating material made of vegetable parchment paper is said to provide uniform dielectric strength and good machineability at less cost than other paper materials presently being used in coil windings. Minimum average dielectric strength in volts per mil of a two mil sheet of Patapar Insulating Parchment, or the weakest point of the sheet at which voltage breakdown will occur, is 321 volts as compared with 336 volts for kraft paper, and 308 volts for glassine paper. Other characteristics are: good machineability on automatic or semi-automatic coil winding equipment, an etched surface which firmly anchors the coil wires to the paper and prevents the completed coil stock from telescoping, high abrasion resistance to eliminate guttering and to prevent the wire from wearing through the paper, good resistance to Class A temperatures (up to 105 degrees C), uniform tensile strength in both machine and cross direction, permanent wet strength so that the paper will accept encapsulating resins without losing insulating properties and an extremely low ash content proving purity. Paterson Parchment Paper Co. Bristol, Pa.

Write No. 154 in Box on Inquiry Card

Miniaturized Alumina Ceramics

With addition of new raw material processing facilities, Diamonite is now delivering miniaturized alumina ceramic parts and components on a full production basis. The company can now offer improved physical and dielectric strengths and low loss factors in a material that is easily metallized and vacuum tight. Research and development for the complete fabrication of even the most intricate requirements in high alumina ceramic miniatures is underway. Diamonite Products Manufacturing Co., Shreve, Ohio.

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Phenolic Resins

Where low-cost, light-weight insulators with good dimensional stability are required, electrical-grade phenolic resins offer a variety of additional properties for a wide range of applications. Some of these compounds are formulated especially for molding around large metal inserts. Each fulfills, within its

Ceramo® Thermocouple Wire Meets Severe Conditions

Where Durability, Hi-Temp Resistance Are Needed

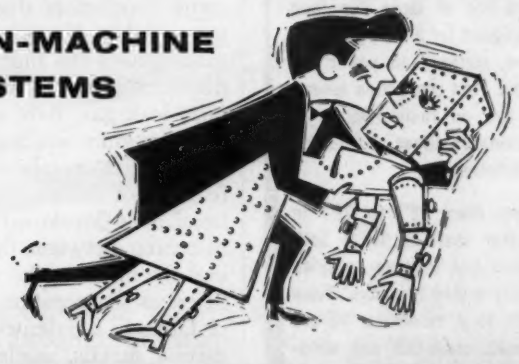
Ceramo® thermocouple and thermocouple extension wires are designed specifically for severe conditions—conditions where ordinary T/C wires are inadequate. First developed by Thermo Electric, "Ceramo" wires incorporate ceramic insulation with overall metal sheathing. They'll solve your problems of high temperature, abrasion, chemical or corrosive action, pressure and difficult installation. You can bend them to almost any shape. As extensions, you can often use them without conduit. And under these conditions they'll outlast comparable standard types many times—with no significant difference in response. Choice of conductors in all standard calibrations and various sheath materials for temperatures up to 3000°F. Conductors—36 to 12 gage. Overall diameters—1/25" to 7/16" for thermocouples; ⅛" and ¼" for extensions.

Write for Bulletin No. 31-300-8

Thermo Electric Co. Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

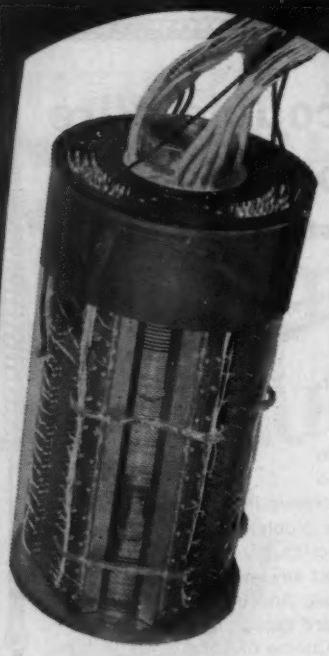
CIRCLE NO. 91 ON INQUIRY CARD

MAN-MACHINE SYSTEMS



The Litton Marine Tactical Data System (AN/ASA-27) is a digital computer-centered system using CRT and numerical displays, and advanced read-in/read-out equipment. Unique interface components integrate the system with sensing and communications equipment. It is designed to aid Marine assault forces in combatting any air threat the enemy can mount. If your discipline can contribute to further advancement in this area, write to Mr. S. L. Hirsch.

LITTON INDUSTRIES Electronic Equipments Division
Beverly Hills, California



NEW SERIES of Antenna SLIP RING Assemblies

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Assemblies vary from 12" to 72" in length, are either shaft or flange ball-bearing mounted and may be specified with hermetically sealed housings. Noise levels are held to a minimum. So are intercircuit losses, cross-talk and radiation, through proper shielding.

For complete information, write:

SCA

SLIP RING COMPANY of AMERICA

3612 West Jefferson Blvd., Los Angeles 16, Calif.

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COMPONENTS DIGEST

intended field of application, a given set of requirements. For example: one provides high dielectric strength at elevated temperatures; another offers good arc resistance; while still another has a low dissipation factor and high volume resistivity. Several are designed to meet military specifications. In electrical applications where exposure to high humidity for long periods presents a problem, diallyl phathalate molding compounds reinforced with Orlon or glass fibers are giving highly dependable service. These materials retain high insulation values over extended periods at relative humidities above 90 percent, do not corrode metal inserts, exhibit consistently reproducible arc resistance, and provide virtual freedom from cold flow and creep. Other characteristics include good electrical properties, low water absorption, and high impact strength. Durez Plastics Div. of Hooker Chemical Corp. No. Tonawanda, N.Y.

Write No. 389 in Box on Inquiry Card

Silico-Ceramics For Hi-Temp Seals

Glass has been the conventional sealing material, but at temperatures greater than 425°F, most glasses become conductors due to their alkaline ion mobility. Use of ceramics to replace glass solved the high temperature conductivity problem, but since true ceramics leak gas, they were of no use for high pressure sealing purposes. Silico-ceramics, a combination of the best features of both glass and ceramic material, was developed to provide a close matching between the sealing material and the metals to be sealed. At Physical Sciences Corporation a close matching of Durock, a patented silico-ceramic, to certain metals, made possible the development and manufacture of a wide range of conductors, cables, connectors and potting material. Although recently developed, these silico-ceramics have been tested over many months at extreme temperatures and pressures and in nuclear fluxes both in the laboratory and in the field. Using Durock, connectors in most standard configurations are sealed for use at 1200°F ambient. Test of the seals indicates leak rates of 2 x 10cc of helium per second and a safe pressure in the standard subminiature connector series of 1000 psi at 1185°F. Effects of radiation on the seals are controlled by eliminating boron, cobalt, nickel, and other high-cross-section-capture materials to obtain a barns capture of less than 20, which is lower than the stainless steel to which the seals are mated. Use of Durock as insulation for magnet wire permits continuous operation at 1000°F. Three standard Durock potting compounds are available in maximum temperature ranges of 2000°F, 3000°F, and 4000°F.

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Insulation Literature

A number of manufacturers are offering literature and catalogs on insulation materials. We are presenting those brought to our attention that are of continual use to designers of electromechanical components and systems. For your free copy write the appropriate number in the box on the reader service card.

A machine formable insulation for stator assemblies is produced by W. J. Ruscoe Co., Akron, Ohio. Free ten foot sample.

Write No. 136 in Box on Inquiry Card

Technical data on Class H, Class F and Class B insulating varnishes that provide a full range of choice in thermal rating and physical and electrical properties, in types of solvents and in curing schedules. Sherwin-Williams Co., Cleveland, Ohio.

Write No. 137 in Box on Inquiry Card

Test report, used as a guide in wire selection, covers a series of thermal aging tests that determine the compatibility of a numbr of magnet wires with encapsulating compounds. Essex Wire Corp., Fort Wayne, Indiana.

Write No. 138 in Box on Inquiry Card

Hysol Corp. of Olean, N.Y., has published a "Systems Selector" covering a line of epoxy encapsulating compounds that deliver superior insulation, moisture, chemical and abrasion resistance.

Write No. 139 in Box on Inquiry Card

Data sheets and samples on extruded silicone rubber fiberglas sleeving can be had from Bentley-Harris Mfg. Co., Conshohocken 6, Pa.

Write No. 142 in Box on Inquiry Card

Alumina-silica fibers called Fiberfrax are light in weight, yet physically strong. With their low thermal conductivity, these fibers will withstand continuous use at temperatures up to 2300° F and can be used at higher temperatures for shorter periods of time. Booklet describes the properties and the many forms available. Carborundum Co., Niagara Falls, N.Y.

Write No. 144 in Box on Inquiry Card

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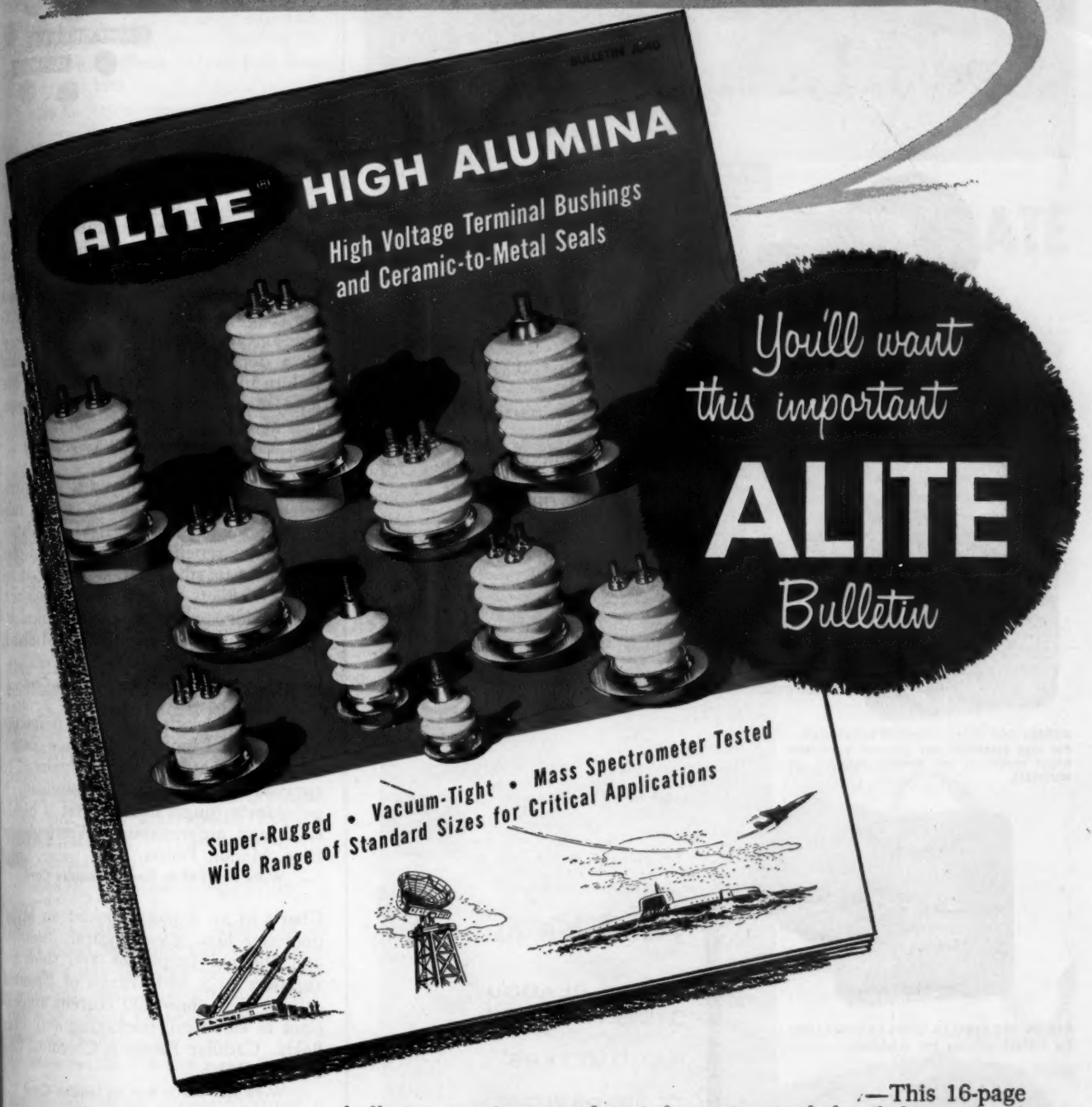

—This 16-page bulletin contains complete information and detailed specifications on the industry's broadest standard line of hermetic bushings. Gives important performance data on ALITE High Alumina Ceramic —complete details on Alite's electrical properties, mechanical strength, temperature resistance, etc. Facts on over 100 standard sizes of high voltage terminals, feed-throughs, cable end seals, plus helpful information on special applications.

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New York Office
60 East 42nd St.

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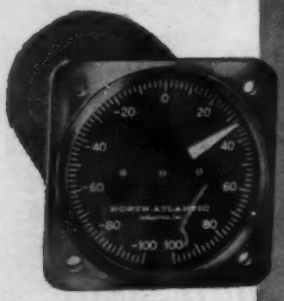

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COMPONENTS DIGEST

32 page manual contains step by step procedures for testing insulation resistance. Methods are outlined for establishing minimum acceptable limits of insulation resistance for a wide range of equipment. Describes simple charts for keeping records of insulation resistance measurements, and how to use them as a dependable means of predicting failure in motors, transformers and like equipment. Associated Research Corp., Chicago, Ill.

Write No. 145 in Box on Inquiry Card

Guide to Silicones includes adhesives, release agents, laminating resins, rubber compounds, electrical insulation and water repellents. Provides an easy reference to silicone materials that resist the effects of time, heat, moisture, weathering, oxidation and chemical attack. Dow Corning Corp., Midland, Mich.

Write No. 146 in Box on Inquiry Card

8 page booklet describes the properties and uses of Limitrak, a surface-coating insulating material. When painted or sprayed on electrical equipment, it provides a tough surface that is high track and arc resistant. Westinghouse Elec. Manor, Penna.

Write No. 147 in Box on Inquiry Card

Charts in an 8 page booklet on Mylar polyester film, give physical, electrical and thermal properties and show resistances to a wide range of chemical attack. Text shows 30 current applications in electrical, packaging and other fields. Cadillac Plastic & Chemical Co., Detroit, Mich.

Write No. 148 in Box on Inquiry Card

High purity ceramic grains, called Alundum, can combine with epoxy resins or silicone compounds for use in potting, encapsulating, or sealing. The ceramic grain, when used in ceramic type mixes or in insulating powders, lends itself to casting, molding or extending of sleeves, shells, tubes, coils and other parts. Detailed application information is available. Norton Co., Worcester, Mass.

Write No. 149 in Box on Inquiry Card

Properties of Havelex, a rigid inorganic insulating material composed of special glass reinforced with mica, are listed. Use of Havelex permits continuous operation at 1000°F with high dielectric strength, arc resistance, and no moisture absorbtion. Various shapes

parts include terminals, switchgear, vacuum tubes, coil forms, insulators, brush holders, actuators, connector inserts and many others. Haveg Ind. Inc., Wilmington, Del.

Write No. 150 in Box on Inquiry Card

The Mosinee Paper Mills Co. of Mosinee, Wisc., has a free data file containing samples of quality laminates made from saturating and impregnating papers.

Write No. 391 in Box on Inquiry Card

Data on silicon rubber tapes of a variety of types is available from Conn. Hard Rubber Co., New Haven, Conn.

Write No. 392 in Box on Inquiry Card

"Mica Paper for Electrical Insulation" (1960 edition) contains complete data on forms available, types of binders, applications, properties, NEMA standards and MIL specs. Should be useful for designers of rotating electrical equipment, electronic gear, capacitors and instruments. Mica Insulator, Div. of Minnesota Mining and Mfg. Co., Schenectady, N.Y.

Write No. 119 in Box on Inquiry Card

Alite High Alumina Ceramics contains information and detail specifications on high alumina ceramics with important performance data on electrcal properties, mechanical strength, temperature resistance and other properties applicable to high terminals, feed throughs, cable end seals and special applications. Alite Div., U.S. Stoneware, Orrville, Ohio.

Write No. 120 in Box on Inquiry Card

Data sheets and a 1960 edition of an Epoxy Resin Selection Chart are available on a one package system for encapsulating and impregnating stators and coils. John C. Dolph, Monmouth Junction, N.J.

Write No. 121 in Box on Inquiry Card

Vol. 1, No. 1 of a new "Journal of TEFLON" contains articles of interest to all users and designers of electrical components wire and cable. E. I. du Pont de Nemours & Co., Wilmington, Del.

Write No. 122 in Box on Inquiry Card

A new reference book devoted exclusively to the use of vulcanized fibre for electrical insulation is now available from Spalding Fibre Co., Inc., Tonawanda, New York.

Write No. 123 in Box on Inquiry Card

An electrical and physical properties chart on epoxy solventless varnishes, a dielectric material that penetrates and insulates, is available from Furane Plastics, Inc., Los Angeles, California.

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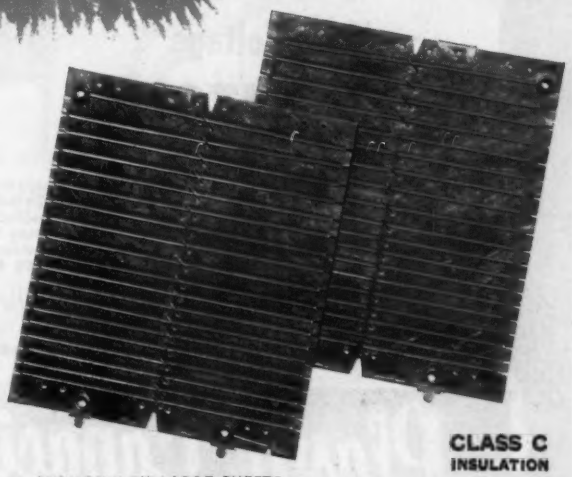
"For Maximum Performance"

NEW ENGLAND MICA

Y-26 HIGH HEAT MICA PLATE

Y-26
HIGH HEAT MICA PLATE IS COMPLETELY INORGANIC, HAS HIGH REFLECTIVE VALUE AND IS RESISTANT TO 650° CENTIGRADE



CLASS C INSULATION

AVAILABLE IN LARGE SHEETS OR PIECES STAMPED TO YOUR DIMENSIONS.

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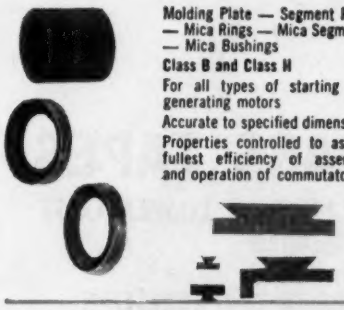

Molding Plate — Segment Plate — Mica Rings — Mica Segments. — Mica Bushings
Class B and Class H
For all types of starting and generating motors
Accurate to specified dimensions
Properties controlled to assure fullest efficiency of assembly and operation of commutators

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Sheet, roll and tape forms
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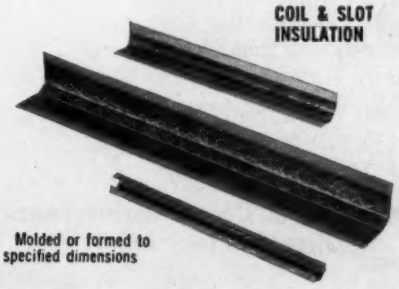

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MICA TUBING

Round, square, rectangular
Class B and Class H

Tell us your area of interest and we will send generous samples for testing — or, send drawings for quotation and learn how you can have better insulation at lower cost.

NEW ENGLAND Mica CO., INC.

WALTHAM 54, MASSACHUSETTS

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TYPE LK rectangular
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If you require a smaller capacitor with much longer life, find out about our Type LK. Designed for 4 times the life of MIL-C-25A with case sizes as much as 80% smaller.
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For Coil Wrappers — Protective Coverings
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ALSO AVAILABLE No. 112 HEAT CLEANED
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FOR PLASTIC REINFORCEMENT
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for identification. (any color)
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RUSCO Engineered Products since 1938

CIRCLE NO. 85 ON INQUIRY CARD

COMPONENTS DIGEST

The Mica Industry Association, Inc. of New York, N.Y. has published a booklet on natural mica for industry. Contains pertinent design information for engineers.

Write No. 143 in Box on Inquiry Card

Two insulating materials, Armalon and Lecton, deliver a range and balance of electrical, thermal, chemical and mechanical properties. Available from E. I. duPont de Nemours Co., Wilmington, Del.

Write No. 126 in Box on Inquiry Card

Complete information on vinyl tape available from H. K. Porter Co., Philadelphia, Penn.

Write No. 127 in Box on Inquiry Card

13-page booklet on paraplex and monoplex plasticizers contains detailed technical information on properties and applications. Rohm and Haas Co., Philadelphia, Pa.

Write No. 128 in Box on Inquiry Card

Union Carbide, New York City, has collected a lot of information on the applications of their BAKELITE epoxy resins.

Write No. 129 in Box on Inquiry Card

Minn. Mining & Mfg. Co., St. Paul, Minn. has recently marketed a polyester film electrical tape with a non-corrosive, pressure sensitive, thermosetting adhesive on both sides. Complete data and information available.

Write No. 130 in Box on Inquiry Card

Free samples of Varglas Silicone Class H tubing and sleeving for applications requiring prolonged heat endurance at temperatures up to 260°C are available from Varflex Sales Co., Inc., Rome, N.Y.

Write No. 131 in Box on Inquiry Card

Technical data on marine cable insulation is available from Raybestos-Manhattan Inc., Manheim, Pa. Formulated on an aesbestos base paper, the tapes have superior qualities of heat, water and corrosion resistance, excellent dielectric strength, good handling strength and meet MIL specs; cost per unit of area is low.

Write No. 132 in Box on Inquiry Card

Data sheets on Diall molding compounds that are flame resistant and heat resistant are available from Modern Plastics Co., Los Angeles, Cal.

Write No. 133 in Box on Inquiry Card

Application data and samples of RTV silicone rubber, a new liquid rubber that cures without heat and is useful from −70 to 600 F is available from General Electric in Waterford, N.Y. The silicone rubber is recommended for sealing, electrical insulation and flexible molds.

Write No. 134 in Box on Inquiry Card

Flame resistant epoxy in custom molded parts or as a liquid epoxy resin is available from Epoxy Products of Irvington, N.J.

Write No. 135 in Box on Inquiry Card

Containing samples for experimental tests, a free kit is a practical aid in suggesting answers to materials-selection problems for products requiring the physical, chemical and electrical characteristics of industrial plastics and fibre materials. Samples, selected in contrasting categories to afford a complete detailed study of each material, include washers, insulation, bushings, gaskets, cutting sticks and boards, gear blanks, key tags, slot wedges, terminal blocks, arc shields, switch panels, grommets, brush holders, electrode supports, fine pitch silent gears, cams and bearings.

Write on company letterhead to: R. S. Christie & Co., 175 Fifth Ave., New York 10, N.Y.

Write No. 339 in Box on Inquiry Card

Three tables of conveniently organized information provide mechanical and electrical properties of high alumina and steatite ceramics; temperature conversion from centigrade to fahrenheit or vice versa and decimal equivalents of fractions, in increments of 1/64. Also included are designs for ceramic products. Centralab, Milwaukee, Wisc.

Write No. 345 in Box on Inquiry Card

Case-history bulletin reports on how housings made of Thermaflow, a reinforced polyester molding compound, permitted the development of speed-responsive switches that are more compact, versatile, and maintenance-free than their predecessors. Use of Thermaflow provided a saving of 4 months in development work. Dielectric strength of Thermaflow eliminated the need for insulating bushings, terminal strips, fiber spacers, etc., which were required in previous models. Atlas Powder Co., Wilmington, Del.

Write No. 346 in Box on Inquiry Card

We talk a synchronous motor language at Bristol Motors!
And that means your language. Whatever your needs—we can answer them quickly, economically, perfectly—with dependable synchronous timing motors from our standard lines—or with motors built to your exact specifications. Speed ranges from 1800 rpm to 1 rp month. Shaft length, voltage variations, shift and brake action and other special features can be engineered to your requirements. Ask for the Bristol Motors Representative in your area—write for new Catalog 160.
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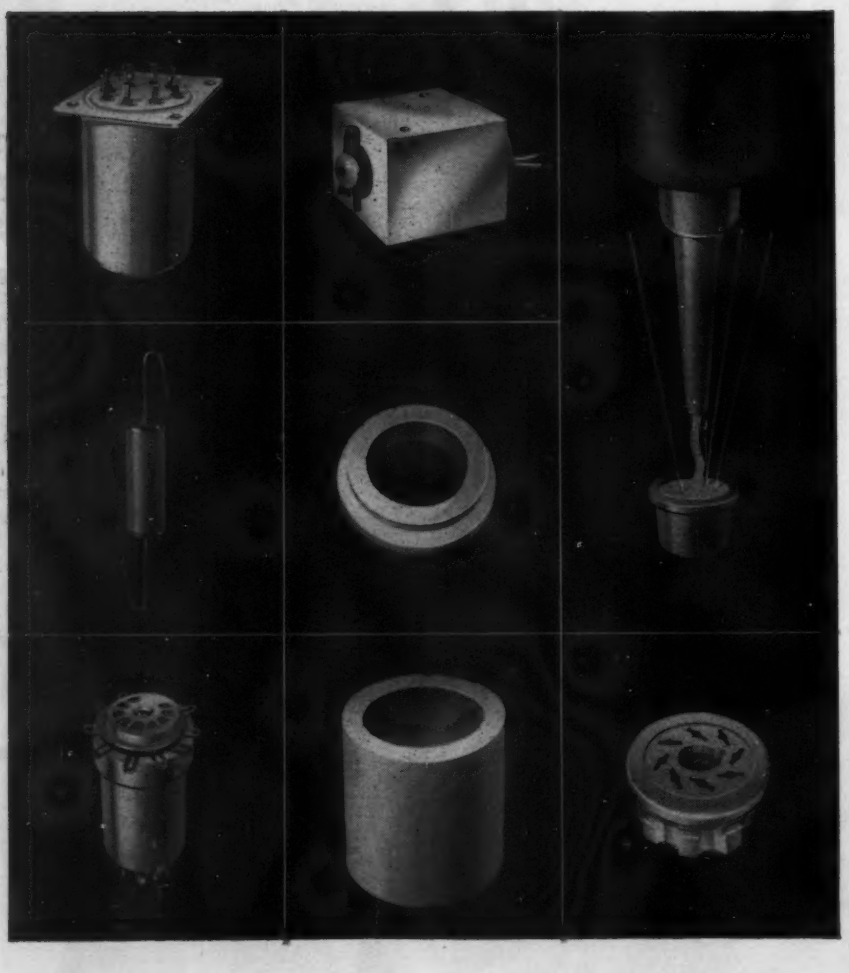
Widen the scope of component design

...with ALUNDUM* high-purity fused alumina grain



Here is a super-refined, highly versatile ceramic grain that gives electronic component designers real creative latitude. With its superior electrical and mechanical properties to work with, even the most advanced design concepts can be translated into practical products efficiently and economically.

Electrochemically refined to extreme purity, the outstanding performance of this Norton ALUNDUM Grain in 500 and 900 mesh size, has long made it a favorite for coating the heaters of radio and television tubes. It's readily available for use throughout the electronics industry — not only in the above mesh sizes but also in a large range of coarser sizes — for virtually limitless applications.

For example, ALUNDUM grain combined with epoxy resins or silicone compounds makes possible superior potting, encapsulating, and sealing agents. Again, used as a basic ingredient in ceramic type mixes or in insulating powders, it readily lends itself to casting, molding or extruding of sleeves, shells, tubes, collars, etc. And in every case, it makes design easier . . . processing more profitable.

Check the exceptional characteristics of ALUNDUM Fused Alumina Grain in the table below. Then get in touch with a Norton Engineer for specific details on your precise requirements. He'll be glad to describe the application of this and other types of Norton Refractory Grain to electronic component design. Write to NORTON COMPANY, Refractories Division, 68 New Bond St., Worcester 6, Mass.

ALUNDUM Fused Alumina Grain Gives You these Superior Properties . . . *and many more!*

High Dielectric Strength

High Electrical Resistance

High Heat Conductivity

High Resistance to Thermal Shock

High Mechanical Strength

High Dimensional Stability

Extreme Hardness

Excellent Abrasion Resistance

Available in a wide range of grain sizes

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NORTON

REFRACTORIES

Engineered... Rx ...Prescribed

Making better products . . . to make your products better

CIRCLE NO. 87 ON INQUIRY CARD

COMPONENTS DIGEST

Describing how thin film coatings solve product problems, a 12 page booklet contains information on the properties of fluorocarbon coatings, silicones, epoxy resins and other coatings. Included are samples of successful applications that have frequently simplified operations, cut costs and improved products for various industries. Nat. Glaco Chem. Corp., Chicago, Ill.

Write No. 356 in Box on Inquiry Card

12 pages of properties and application data on mill shapes of nylons, TFE fluorocarbons, polycarbonates, chlorinated polyethers and cross-linked polystyrene. Also includes information on Fluorosint, a new TFE base resin and nylon pressure hose and tubing. Polymer Corp. of Penna., Reading, Penna.

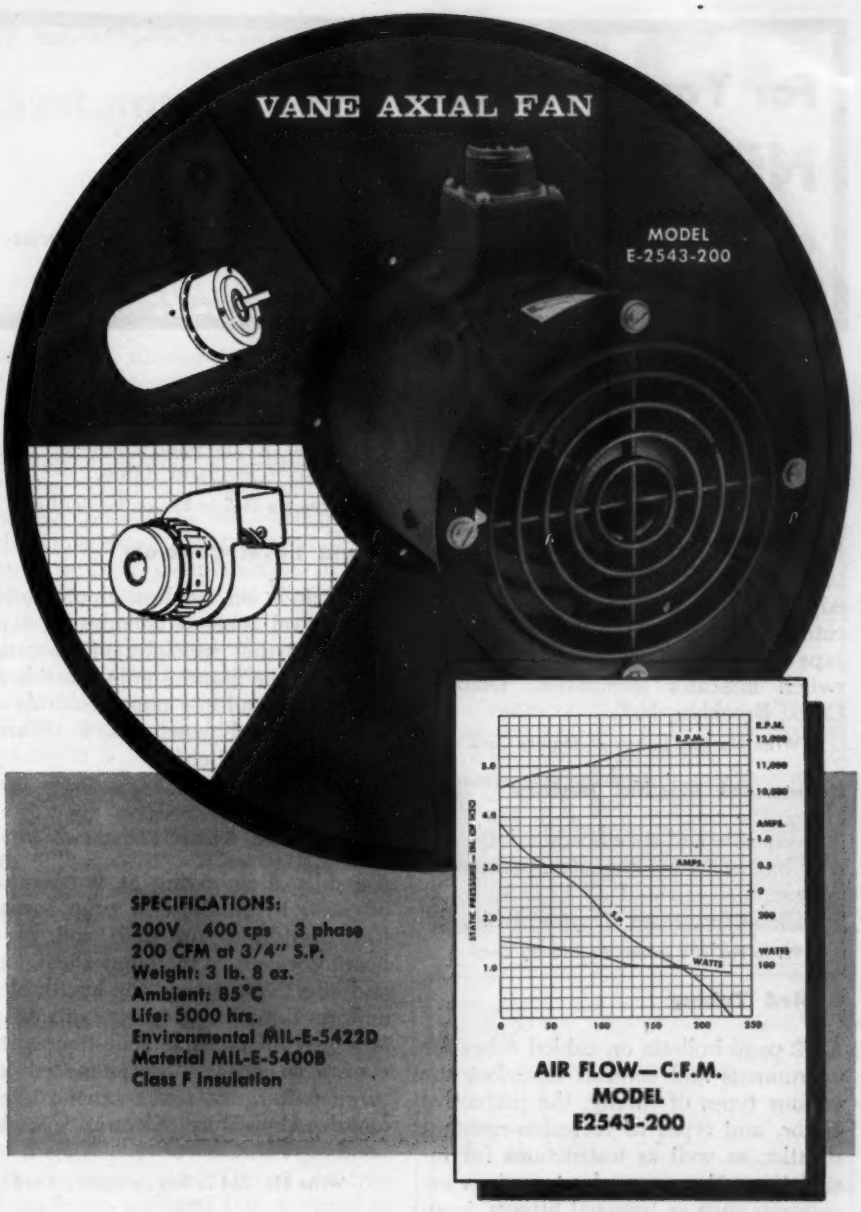
Write No. 357 in Box on Inquiry Card

Three new epoxy resins displaying novel structure, reactivity and curing characteristics are described in a twenty-four page booklet. Oxiron epoxy resins are distinguished by their ability to peroxide cure through reactive double bonds as well as to cross link through conventional epoxy curing agents. These materials can be formulated for a wide range of superior properties and often offer attractive production economies, according to the new brochure. Cure systems are thoroughly described by means of actual formulas used to obtain a variety of end properties. Thirteen different tables are used to present the physical and mechanical properties of the cured and uncured resins while ten graphs illustrate such properties as high heat distortion points, exotherm and molecular structure. Food Machinery and Chemical Corp., New York, N.Y.

Write No. 337 in Box on Inquiry Card

One-part 100% epoxy adhesive requires no mixing, weighing, or metering. As a truly thixotropic paste, it easily applies to vertical surfaces without any running or sagging and requires short heat curing to form a strong bond, stable at 200 C. Adheres well to all temperature-stable materials and exhibits a high dielectric strength. Metachem Resins Corp., Cranston, R.I.

Write No. 393 in Box on Inquiry Card



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WRITE TODAY FOR OUR NEW CATALOG

CIRCLE NO. 88 ON INQUIRY CARD

For Your Reference File
NEW CATALOGS

For your free copy of the literature listed on this page, enter the appropriate number of the item on the Inquiry Card.

Pilot Lights

Categories of pilot lights, covered in 24 pages, include: sub-miniature indicator lights, pilot lights with built-in resistors for neon lamps, enclosed-type assemblies for incandescent and neon lamps, edge lighting assemblies, oil-tight indicator lights, assemblies with dimmer caps and press-to-test and press-to-switch indicator assemblies. Dialight Corp., Brooklyn, N.Y.

Write No. 358 in Box on Inquiry Card

Permanent Magnet Motors

Performance and specification data on a new line of 1⅛ in. diameter, permanent magnet motors rated at 1/45 to 1/30 hp. Globe Industries, Dayton, Ohio.

Write No. 359 in Box on Inquiry Card

Cabled Tubing

A 12 page bulletin on cabled tubes for instruments and controls describes the various types of tubing, the protective armor, and types of corrosion-resistant sheaths, as well as instructions for installation. Also covered are various accessories such as terminal fittings, junction boxes and clamps. Crescent Insul. Wire & Cable Co., Trenton, N.J.

Write No. 360 in Box on Inquiry Card

Moldings

Comprehensive analysis of large polyolefin moldings used for neutron moderation and shielding on original equipment components covers three types: branch-type polyethylene, linear-type polyethylene and newly developed polypropylene. Selected references of typical applications are included. Amer. Agile Corp., Bedford, Ohio.

Write No. 361 in Box on Inquiry Card

Explosion-Proof Housings

Cast from aluminum alloy, explosion proof housings were tested at pressures up to 275,000 pounds force exerted against the cover. They are particularly suitable for use with control panels because of their light weight. Explosion-proof design information, together with complete listings of housings are included in a 16 page bulletin. Adalet Mfg. Co., Cleveland, Ohio.

Write No. 362 in Box on Inquiry Card

Liquid Level Controls

Information on floatless, electrode-type liquid level controls includes an explanation of the principles of operation, details of the 2-and 3-Pole controls and enclosures, multiple pump controls and special control panels. C. F. Warrick Co., Berkley, Mich.

Write No. 363 in Box on Inquiry Card

Combustion Tube Furnaces

Capable of operating at temperatures of 2200°F, combustion tube furnaces have vestibules on each end of the heating chamber to reduce heat losses and effectively extend the length of the uniform hot zone. Heating units can be arranged for multiple zone temperature control to provide optimum temperature uniformity over an extended length. Hevi-Duty Electric Co., Milwaukee, Wisc.

Write No. 364 in Box on Inquiry Card

21 Mercury Switches

Specs on 21 special-purpose mercury switches are given along with a variety of terminals and mounting clips. Includes a chart showing approximate locked rotor current ratings for electric motors. Gardos Corp., Bloomfield, N.J.

Write No. 365 in Box on Inquiry Card

Microwave Components

26 pages provide complete product information on microwave switches, power dividers, directional couplers and other components plus antennas and antenna systems. Also included is a special data section devoted to a series of practical charts and graphs to aid the microwave engineer. Transco Products Inc., L. A., Calif.

Write No. 348 in Box on Inquiry Card

Germanium Transistors

Availability catalog covers virtually every known germanium transistor type for applications in computers, aircraft, missiles, military, marine and general industry. The 412 types meet E.I.A. specs and Mil-T-19500A. Electronic Transistors Corp., North Bergen, N. J.

Write No. 349 in Box on Inquiry Card

Semiconductors

Major specs such as breakdown voltages, current capacity and operating temperature range are covered on five lines of semiconductors including germanium industrial power transistors, audio and switching transistors, mesa transistors, silicon rectifiers and silicon zener diodes. Also contained is information on a reliability program in which industrial semiconductors are subjected to electrical, mechanical, environmental and life tests identical of those required for Mil specs. Motorola Inc., Phoenix, Ariz.

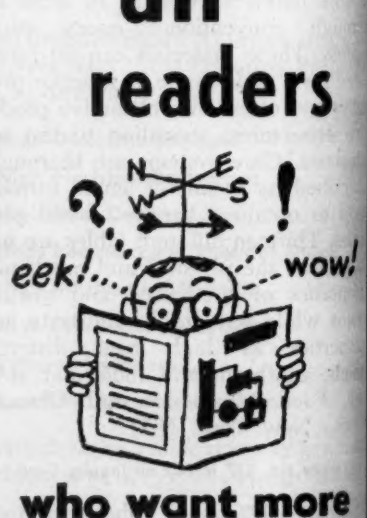
Write No. 347 in Box on Inquiry Card

Custom-Built Elastomers

"Achieving Better Designs with Custom-Built Elastomers" describes the origin and composition of natural rubber and nine synthetic elastomers and lists their physical and chemical properties, processing properties and environmental resistance characteristics. Lord Mfg. Co., Erie, Penna.

Write No. 354 in Box on Inquiry Card

for all readers



who want more information

Two spanking new inquiry cards have been bound into the back of this magazine. All of your circled inquiries will be processed with lightning dispatch

New Electromechanical Components For Electromechanical Systems

Gear Motors

Gear motor's gear train employs the first worm cut directly on the motor shaft for high efficiency. Shaft worm and secondary worm are case hardened for maximum life. The high speed first gear is of fibre for minimum noise and the low speed gear is bronze for maximum torque. Both have hubs for accurate alignment. Ten standard single and double worm reduction models are available with shaft outputs ranging from 10 to 750 rpm. The shaft position is easily changed to six 30 degree positions by means of 6 screws. Motor shaft runs on ball bearings, gear shafts on bronze sleeves bearings. All gears are lifetime lubricated and sealed. Carter Motor Co., Chicago, Ill.

Write No. 160 in Box on Inquiry Card

Constant-Torque Tube Motor

The long, narrow tube shape of a constant-torque mechanical spring motor opens up many new applications, for example internal mounting in drums, instrument chart drives, long slender members, tubes, and the like. Developing a constant torque of 6 lb-in. through 50 revolutions of the output pulley at all positions of cable extension, the motor itself would fit within a 2 in. diameter cylindrical cavity of 8 in. length. A smaller model of the motor, which develops a constant torque of 3 oz-in. through 50 revolutions, would fit in a ¾ in. diameter cavity of 3¾ in. length. Hunter Spring Co., Div. of American Machine & Metals, Inc., Lansdale, Pa.

Write No. 180 in Box on Inquiry Card

Elapsed Time Indicator

Easily and instantly read at distances up to six feet, a miniature elapsed time indicator presents three digits at a time. Presentation is on a single reading line in place of the concentric circle, dial type. Each of the three white numerals is ⅛ of an inch high and is prominently displayed on a dull black counter drum. The indicator provides readings from 000 to 999 hours with return to 000, in one-hour increments. Bowmar Instrument Corp., Fort Wayne, Ind.

Write No. 338 in Box on Inquiry Card

Overtemperature Protector

Said to be the smallest overtemperature protector, a device called Klixon 5891 was designed specifically for sub-fractional horsepower motors one inch in diameter and larger, but is equally suitable for small solenoids and transformers. Responsive to both current and temperature, the protector is designed with a compensating heating element to ensure that the snap-acting, disc-type sensing element will follow closely the temperature changes of the component to be controlled. Temperature levels of protection are 150, 175 and 200 degrees C. Maximum contact capacity is 5 amps at 27 volts d-c or 120 volts a-c. Units conform to MIL-M-7969 and MIL-M-8609, and when mounted in equipment they comply with MIL-E-5272. Texas Instruments, Inc., Metals and Controls Div., Attleboro, Mass.

Write No. 318 in Box on Inquiry Card

Span-Adjustable Recorder

Null-balancing type recorder employs a line driven synchronous converter and amplifier to control a two-phase motor which rebalances the measuring circuit. Millivolt input, either direct or from a transducer, converts into a visual indication and a permanent chart record. Span adjustment in millivolts is indicated on a calibrated dial. The recorder covers spans between 1 and 250 mv, placing the lowest nominal span at 5 mv (1-10) and the highest nominal span at 125 mv (25-250). Zero adjustment is marked in arbitrary units from 0-1000 and any span selected may be shifted (without change) over a maximum of ±50 mv. Weston Instruments Div., Daystrom, Inc., Newark, N.J.

Write No. 344 in Box on Inquiry Card

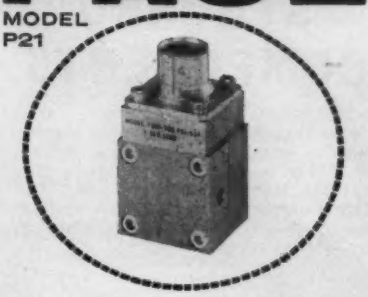
Cooling Fan

Adaptable to airborne electronic chassis or compartment cooling wherever constant airflow is desired despite changing inlet pressures, a fan and flow control unit provides 2000 hours of controlled air volume from sea level to 30,000 feet. Task Corp., Anaheim, Cal.

Write No. 174 in Box on Inquiry Card

PACE

MODEL P21



magnetic reluctance

PRESSURE TRANSDUCER

Ranges: 1 to 1,000 psi — Gage, Differential or Absolute.

Pressure Media: Corrosive liquids and gases, both sides.

Insensitive to Shock and Vibration — Not oil filled.

Withstands Extreme Overpressure.

PACE's P21 Transducer (only 1 3/32" square) is miniaturized for missile, rocket and aircraft flight installations.

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MIL-TESTED SYNCHRO COMPONENTS

PRECISION AND PROVEN—A complete line of electro-magnetic rotary components manufactured in accord with MIL-S-20708, ARP-461, MIL-E-5400, to military and commercial specifications. More than 100 designs to choose from in standard frame sizes, with electrical and mechanical configurations engineered to any specific system requirement.

SIZE 8 SYNCHRO (ACTUAL SIZE)

SIZE 8 SYNCHROS

MIC TYPE AND MODEL NO.	INPUT VOLTAGE 400	INPUT CURRENT AMPS	OUTPUT VOLTAGE VOLTS	PHASE SHIFT Deg. Lead (Max.)	IMPEDANCE Ohms Zin	Zout	Null Voltage
TORQUE RECEIVER	ROTOR AS PRIMARY						Electrical Tracking Error
9708-001	26	.15	11.8	12	45+j170	19+j69	1°
TORQUE TRANSMITTER							
9708-002	26	.14	11.8	12	45+j170	19+j69	1°
9708-032	26	.12	11.8	11.8	62+j235	13+j51	1°
008-235	26	.18	11.8	12	54+j205	12+j45	1°
008-236	115	.05	50	13	850+j3200	210+j790	1°
008-239	115	.04	56	17	833+j3205	611+j2345	1°
008-244	90	.068	11.8	12	88+j270	12+j35	2°
CONTROL TRANSFORMER	STATOR AS PRIMARY						
9708-007	11.8	.067	22.5	17	1000+j3760	610+j2305	2°
9708-033	11.8	.120	23.5	12	160+j590	27+j61	2°
008-334	11.8	.079	23.5	12	300+j1060	80+j340	2°
008-335	11.8	.075	23.5	12	610+j2300	150+j580	2°
008-337	90	.022	52.5	12	470+j1770	810+j3760	10°
008-340	11.8	.055	23.5	12	610+j2260	150+j580	2°
008-343	11.8	.120	23.5	11	160+j600	27+j61	2°
RESOLVER TRANSMITTER							
9708-004	11.8	.100	21.2	12	220+j650	50+j205	2°
VECTOR RESOLVER							
9708-009	11.8	.230	25	12	200+j650	27+j91	2°
LINEAR TRANSFORMER	ROTOR AS PRIMARY						
9708-008	26	.130	—	10	50+j220	80+j350	—
9708-026	26	.120	—	16	50+j220	80+j350	—
CONTROL DIFFERENTIAL	STATOR AS PRIMARY						
008-605	11.8	.120	12.3	12	60+j200	22+j91	2°

SIZE 11 SYNCHROS

MIC TYPE AND MODEL NO.	INPUT VOLTAGE 400	INPUT CURRENT AMPS	OUTPUT VOLTAGE VOLTS	PHASE SHIFT Deg. Lead	IMPEDANCE Ohms Zin	Zout	Null Voltage
CONTROL DIFFERENTIAL	STATOR AS PRIMARY						
9711-003	—	.055	11.8	11.8	220+j1000	220+j1000	2°
9711-005	208-115/26 4ϕ	.115	11.8	11.8	50+j187	17+j64	2°
CONTROL TRANSMITTER	ROTOR AS PRIMARY						
9711-001	208-115/26 4ϕ	.25	11.8	4.0	34+j128	10+j39	1°
9711-005	115/26 4ϕ	.115	50.0	0.4	600+j2282	200+j760	1°
RESOLVER TRANSMITTER							
9711-001	—	.115	400	11.8	272+j1030	100+j380	1°
9711-021	—	.115	400	11.8	400+j1700	61+j270	1°
014-207	208-115/26 4ϕ	.25	400	11.8	400+j1700	61+j270	1°
9711-001	208-115/26 4ϕ	.25	400	11.8	400+j1700	61+j270	1°
VECTOR RESOLVER							
9711-001	115/26 4ϕ	.115	400	11.8	400+j1700	100+j380	1°
9711-021	115/26 4ϕ	.115	400	11.8	400+j1700	61+j270	1°
014-207	208-115/26 4ϕ	.25	400	11.8	400+j1700	61+j270	1°
9711-001	208-115/26 4ϕ	.25	400	11.8	400+j1700	61+j270	1°
RESOLVER RECEIVER	208-115/26 4ϕ	.115	400	11.8	400+j1700	100+j380	Electrical Tracking Error
9711-001	208-115/26 4ϕ	.25	400	11.8	400+j1700	61+j270	1°
CONTROL TRANSFORMER	STATOR AS PRIMARY						
9711-009	208-115/26 4ϕ	.117	400	12.5	320+j1215	80+j340	2°
9711-015	115/26 4ϕ	.117	400	12.5	320+j1215	80+j340	2°
RESOLVER TRANSMITTER							
9711-002	—	.25	200	25.0	110+j1000	100+j1000	2°
ELECTRICAL RESOLVER	ROTOR AS PRIMARY						
011-414	—	.05	400	12.5	3.0	100+j1015	—	—	4%
SERVO RESOLVER							
011-457	—	100 @ 400 cps 50 @ 1000 cps	200 (3 wire output)	26 @ 400 cps 6 @ 1000 cps	0°C to 70°C ELECTRICAL ZERO 6 + 0.6°	25	—	—	1.5% @ 5° 1.0% @ 15° 0.5% @ 90°

Nominal null values 25 to 125 millivolts depending upon unit.

Write for Size 8 Bulletin 204, and/or Size 11 Bulletin 206

INDUCTION MOTORS OF CALIFORNIA

DIV. OF INDUCTOSYNS CORP., N.Y.

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REPRESENTATIVES IN PRINCIPAL CITIES

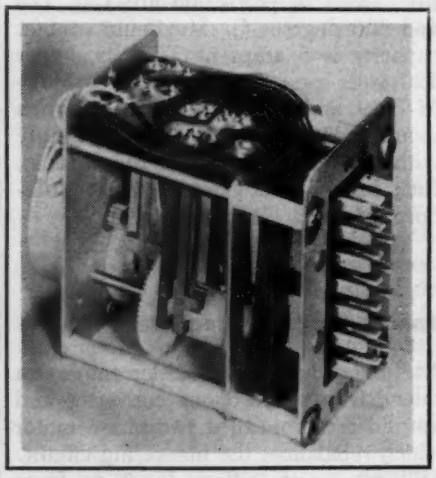
CIRCLE NO. 92 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Sub-Miniature Limit Switch

Designed for use in applications requiring a fixed or fractional number of revolutions of rotating shafts, such as servomechanisms, a limit switch provides mechanical stop protection as well as electrical actuation at each end of the preset limit. Two micro switches are mounted at each end of slide bar, facing one another. Pre-setting of slide bar and positioning of switches results in one switch being normally closed, the other normally open. When a pinion reaches the stop collar, further shaft rotation deflects slide bar to actuate both switches on that end. Use of 21 and 22 tooth pinions allows approximately 1° adjustments throughout the range of 32 turns or 11,520°. Arch Instrument Co., North Quincy, Mass.

Write No. 161 in Box on Inquiry Card



Repeat Cycle Timers

Guaranteed to operate continuously for a minimum of one year, the long life and quiet operation of a repeat cycle timer are achieved by mounting special spring switches in molded contact blocks, while cams, cam followers and gear assemblies are molded nylon. Two printed circuit cables are used to wire 12 output circuits. Parallel cam shafts provide two cycling speeds. Units are available with voltage, cycle time and programming adapted to the application. Simple motor mountings, using only three screws, permit fast motor replacement. A. W. Haydon Co., Waterbury, Conn.

Write No. 163 in Box on Inquiry Card

Low-Cost Transistorized Readout

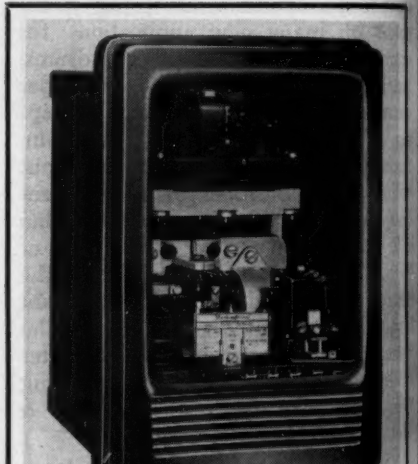
Said to be the lowest power visual readout available, the Trixie (Transistor driver plus Nixie indicator tube) comprises ten medium-voltage NPN transistors in a common emitter configuration with each transistor driving one of the Nixie indicator tubes ten cathodes. A unique circuit design takes advantage of low cost NPN type transistors operating in a breakdown condition, where the current is limited by the indicator tube, resulting in negligible current being drawn by the nine "off" cathodes and preventing damage to the transistor junction. Readout modules can be triggered by signals as low as 3 volts, requiring currents of only 300 microamperes. Burroughs Corp., Electronic Tube Div., Plainfield, N.J.

Write No. 420 in Box on Inquiry Card

Temperature and Pressure Readout

Capable of reading out combinations of temperature and pressure, a digital readout system operates from resistance temperature bulbs in the zero degree to 1400 degree F range and from resistance pressure transducers ranging from zero to 10,000 psi. Accuracy is ½ to 2 percent absolute (depending upon range and transducers). Use of copper wiring to transducers instead of more expensive thermocouple wiring reduces cost significantly. Information is encoded for telemetering allowing remote interrogation. Temperature and pressure may be monitored from as many as 99 different points. Texas Instruments, Inc., Instrumentation Product Group, Houston, Tex.

Write No. 319 in Box on Inquiry Card



Timing Relay

Designed for reverse-power, three-phase applications, a directionally-controlled timing relay is rated 120 volts line-to-line, 5 amps. Main contacts can close 30 amps at 250 volts dc and carry this current for sufficient time to trip a circuit breaker. Features include high sensitivity of 0.02 amp., 120 volts at maximum torque, adjustable timing range from 2.0 to 40 seconds, small-size Flexitest case, and low burden. The relay is completely self-contained. Westinghouse Electric Corp., Pittsburgh, Pa.

Write No. 166 in Box on Inquiry Card

New Electronic Components For Electromechanical Systems

DC Power Supply

Unusually small for its high degree of regulation, only 10½ x 7⅛ x 6 in., a transistorized dual-output d-c to d-c converter drives transistorized circuits in missile checkout and launching equipment. Line static regulation is ± 0.1% for changes from 27.5 to 31.5v, line dynamic regulation is ± 0.050v for input transients of 70v d-c with a duration of 0.2 sec. Static load regulation is ± 0.4% for changes from no load to full load and full load to no load. Perkin Engrg. Corp., El Segundo, Cal.

Write No. 170 in Box on Inquiry Card

Push Button Switches

Adaptable to many variations of switching requirements, push botton switches contain nylon insert molded actuators for ease of operation and long life. Wide choices of contact arrangements provide flexible electrical control. Build-ups can be mounted on one or both sides to insure minimum amount of operating pressure. General Control Co., Boston, Mass.

Write No. 343 in Box on Inquiry Card

Transistor Amplifier

Input and output impedance of a 1 x 1 x 1¼ amplifier is 200,000 and 1,000 ohms respectively. Gain is unity and input and output are isolated. Internal signal limiting prevents overdrive or phase shift for high input signals. Operates from −35 degrees C to 125 degrees C and under MIL E 5272 environmentals. Control Technology Co., New York, N.Y.

Write No. 341 in Box on Inquiry Card

Inductive Loading Reactor

For testing apparatus at various lagging power factors a self-contained loading reactor provides a convenient inductive load which can be made adjustable by using a variable transformer. The reactor consists of a gapped, strip-wound silicon steel toroid core, wire-wound and imbedded in epoxy compound. Entire assembly is enclosed in a compact phenolic case having two 5-way binding posts for connections. The Superior Electric Co., Bristol, Conn.

Write No. 207 in Box on Inquiry Card

Encapsulated Yoke

Epoxy encapsulated, ferrite core deflection yoke for ⅞" neck dia., 70° cathode ray tubes is designed primarily for transistorized military and industrial TV raster and similar applications. The yoke has single ended coils of high inductance to resistance ratio. Flat face CRT pincushion distortion is corrected by 4 anti-pin-cushion, pre-adjusted and pre-aligned magnets without linearity deterioration. Wide impedance range is upward from 110 microhenries. Syntronic Instruments, Inc., Addison, Illinois.

Write No. 171 in Box on Inquiry Card

Servo Amplifiers

Use of semi-conductors in the low-power preamplifier stage achieves high gain with fast response for power amplifiers. Rugged saturable core magnetic amplifiers in the power stages provide reliable driving power for a-c servo motors. The amplifiers, called Trans-mag, operate from a-c or d-c inputs for either 60 cps or 400 cps systems and are designed for open or clsed loop servo systems. Units meet all pertinent mil. specs. Magnetic Amplifiers, Inc., New York, N.Y.

Write No. 317 in Box on Inquiry Card

Single Turn Pot

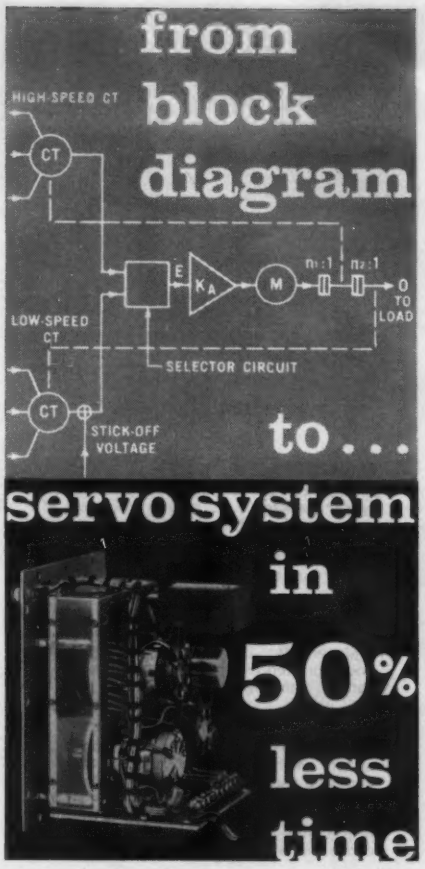
Precision, single turn wirewound potentiometer with a ⅛ inch o.d. is designed for panel trimmer control and servo applications in low and high torque models, with stops or in continuous rotation. Having an all-metal construction, it meets MIL 5272A and applicable portions of JAN R-19 specs. New England Instrument Co., Waltham, Mass.

Write No. 342 in Box on Inquiry Card

Silicon-Carbide Rectifier

Representing a major breakthrough in high temperature, radiation-resistant semiconductors, silicon-carbide rectifiers wtihstand temperatures of 500 degrees and are said to be 100 times less subject to radiation damage than silicon. Typical reverse currents are less than 100 at 50 volts, 400 degrees C. Transistron Electronic Corp., Wakefield, Mass.

Write No. 335 in Box on Inquiry Card



Whether the job demands a servomechanism designed to a system specification, or precision manufactured to your own drawings, Superior's specialized experience and proven capability can bring you important gains in system reliability — often with savings of 50% or more in design-through-production time.

Superior's staff and facilities are devoted exclusively to design and production of electromechanical servomechanisms — and backed by unmatched test engineering and quality control. Packaged servo systems by Superior are today meeting critical performance requirements in missile tracking, fire control, flight simulators, weather radar, many other defense and industrial systems.

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CIRCLE NO. 94 ON INQUIRY CARD

STANDARD AND SPECIAL PURPOSE POWER SUPPLIES

TRANSISTORIZED AC TO DC ELASCO MINISOURCE® POWER SUPPLIES

FIXED AND SEMI-VARIABLE

TRANSISTORIZED
Higher current capabilities in a smaller lighter package . . . greatly improved efficiences and reliability . . . less heat per watt input . . . no filament power losses . . . reduced transformer and rectifier losses . . . no warmup time . . . longer life.

COMPLETE SERVICEABILITY
All components accessible for checking and replacement . . . potting has been eliminated and a printed circuit board incorporated for compact packaging.

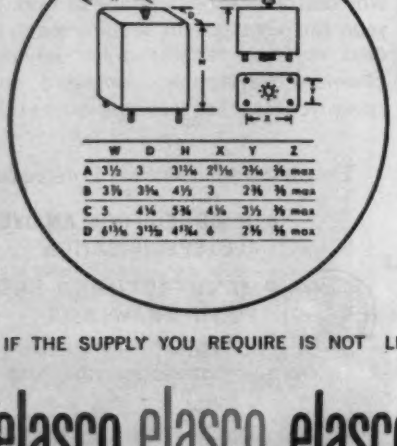
EFFICIENT HEAT TRANSFER
Accomplished by mounting the power transistor on the geometric center of the black anodized aluminum housing, which becomes an efficient black body radiating heat sink . . . Better heat transfer assures more accurate, stable and long-life performance of all components.

FULL PROTECTION
Fusing in the collector of the power transistor protects the supply without affecting regulation.

All standard Minisource® power supplies are furnished with an octal glass to metal header (other terminations available upon request) and packaged in a black anodized aluminum transformer case. There is no extra charge for 400 cycles.

SPECIFICATIONS
VOLTAGE REGULATED — FIXED OR SEMI-VARIABLE * OUTPUT

Input Frequency: 60 cps or 400 cps
Input Voltage: 105-125 VAC
Output Voltage: 4 to 200 VDC
Output Current: 50 to 500 ma
Regulation: Better than 0.5%
Ripple: Less than 0.25%
Polarity: May be used Floating, Positive, or Negative
*Screw driver adjustment on top of semi-variable units.



	W	D	H	X	Y	Z
A	3½	3	3¹³⁄₁₆	2¹⁵⁄₁₆	2¾	⅜ max
B	3⅜	3¾	4½	3	2¾	⅜ max
C	3	4¼	5¾	4¼	3½	⅜ max
D	6¹³⁄₁₆	3¹⁵⁄₁₆	4¹³⁄₁₆	6	2¾	⅜ max

FIXED MINISOURCE

MODEL	VOLTAGE	CURRENT	CASE SIZE
M4.5-50	4.5v.	50 ma	B
M4.5-100	4.5v.	100 ma	B
M4.5-250	4.5v.	250 ma	B
M4.5-500	4.5v.	500 ma	B
M6-50	6v.	50 ma	A
M6-100	6v.	100 ma	A
M6-250	6v.	250 ma	A
M6-500	6v.	500 ma	B
M12-50	12v.	50 ma	A
M12-100	12v.	100 ma	A
M12-250	12v.	250 ma	B
M12-500	12v.	500 ma	B
M22-50	22v.	50 ma	A
M22-100	22v.	100 ma	B
M22-250	22v.	250 ma	B
M22-500	22v.	500 ma	B
M25-50	25v.	50 ma	B
M25-100	25v.	100 ma	B
M25-250	25v.	250 ma	B
M25-500	25v.	500 ma	B
M28-50	28v.	50 ma	B
M28-100	28v.	100 ma	B
M28-250	28v.	250 ma	B
M28-500	28v.	500 ma	B
M30-50	30v.	50 ma	B
M30-100	30v.	100 ma	B
M30-250	30v.	250 ma	B
M30-400	30v.	400 ma	B
M50-50	50v.	50 ma	B
M50-100	50v.	100 ma	B
M50-250	50v.	250 ma	C
M100-100	100v.	100 ma	C
M150-100	150v.	100 ma	C
M200-100	200v.	100 ma	C

SEMI-VARIABLE MINISOURCE

MODEL	VOLTAGE	CURRENT	CASE SIZE
V4-50	3-6v.	50 ma	B
V4-100	3-6v.	100 ma	B
V4-250	3-6v.	250 ma	B
V4-500	3-6v.	500 ma	B
V8-50	5-10v.	50 ma	A
V8-100	5-10v.	100 ma	A
V8-250	5-10v.	250 ma	B
V8-500	5-10v.	500 ma	B
V12-500	10-15v.	500 ma	B
V15-500	10-20v.	500 ma	A
V15-100	10-20v.	100 ma	B
V15-250	10-20v.	250 ma	B
V18-500	15-20v.	500 ma	B
V22-500	20-25v.	500 ma	B
V25-50	20-30v.	50 ma	A
V25-100	20-30v.	100 ma	B
V25-250	20-30v.	250 ma	B
V28-500	25-30v.	500 ma	B
V32-250	30-35v.	250 ma	B
V35-50	30-40v.	50 ma	B
V35-100	30-40v.	100 ma	B
V38-250	35-40v.	250 ma	B
V42-250	40-45v.	250 ma	C
V45-50	40-50v.	50 ma	B
V45-100	40-50v.	100 ma	B
V48-25	45-50v.	25 ma	C
V65-50	60-70v.	50 ma	B
V65-100	60-70v.	100 ma	B
V75-50	70-80v.	50 ma	B
V75-100	70-80v.	100 ma	B

ELASCO can package power supplies in any way the customer may desire (within reason) and to comply with military requirements.

ELASCO inc.

FIVE PRESCOTT STREET, ROXBURY 19, MASSACHUSETTS
Telephone: HIghlands 2-1600

IF THE SUPPLY YOU REQUIRE IS NOT LISTED ABOVE, ELASCO WILL BE HAPPY TO BUILD A MINISOURCE® TO YOUR SPECIFICATIONS.

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CIRCLE NO. 93 ON INQUIRY CARD

ELECTRONIC COMPONENTS

Power Oscillator

Designed for driving high speed motors of the 100,000 rpm type to furnish demodulation signals to amplifier circuits, power oscillators are hermetically sealed and meet the requirements of MIL-E-5272B. Harmonic distortion is less than 8% and the transistorized circuit starts immediately under full load. Input is 5KC ± 5% at + 15 volts (6VA). Metrolog Corp., Los Angeles, Calif.

Write No. 401 in Box on Inquiry Card

Disc Thermistor

A tiny disc thermistor about the size of an aspirin is now available for the first time as a stock item. The unit has its resistance matched to a nominal resistance versus temperature curve within ±5%. Victory Engineering Corp., Union, New Jersey.

Write No. 179 in Box on Inquiry Card

Regulated Power Supply

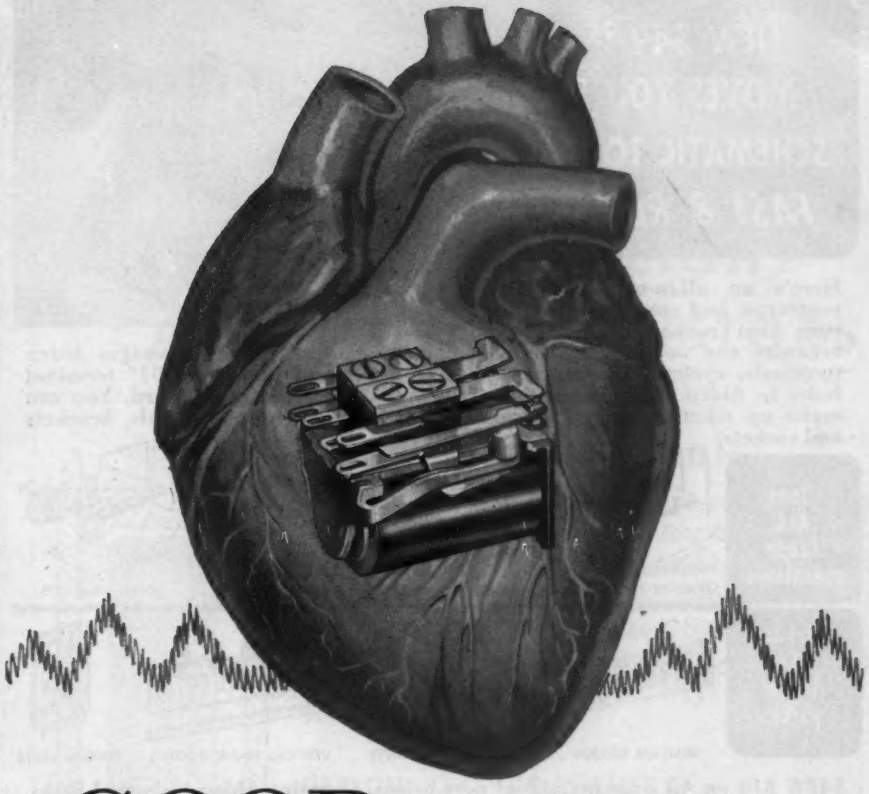
Bantam size, a constant-current-regulated power supply for powering of solid state equipment on the bench or in the rack is transistor and zener diode regulated. It measures only 4.75" wide by 4.5" high by 6.25" deep while providing up to 400 milliamps at a maximum of 30 volts. Regulation is better than 1% against line and no load to full load variations and ripple is less than 5 mv. Output, continuously monitored by a voltmeter and milliameter, is isolated from input line and chassis ground. Matthew Laboratories, New York, N. Y.

Write No. 167 in Box on Inquiry Card

DC to DC Converter

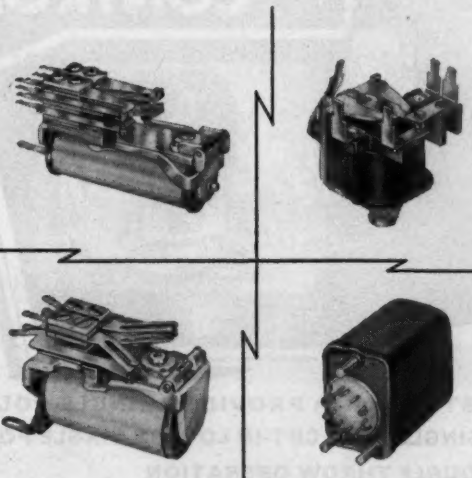
Miniature transistorized d-c to d-c power supplies provide a range of voltage at low current levels. A ringing choke-type converter, using a single Germanium transistor, produces up to 1.75 watts of power and up to 80 percent efficiency. Adjustable by external resistors, output voltages of unregulated units range from 350 to 2100 volts d-c, at load currents of up to 250 microamps. With exception of externally removable transistors, units are completely encapsulated. Maximum ripple is 1 percent rms. American Research Manufacturing Corp., Rockville, Md.

Write No. 340 in Box on Inquiry Card



a GOOD one is important!

• Relays are often referred to as the heart of an electronic control circuit. A good one is essential to efficient performance and longer life. For years Comar has aided manufacturers suffering from relay trouble.



Our relay technicians will show you how to put more vim and vigor in your relay circuits. Send the symptoms... we'll recommend the cure...no obligation.

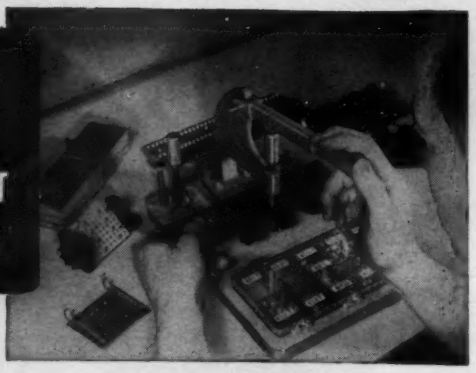
comar electric

3349 ADDISON STREET, CHICAGO 18, ILLINOIS

RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

CIRCLE NO. 95 ON INQUIRY CARD

NEW $49.95 KIT MOVES YOU FROM SCHEMATIC TO CIRCUIT *FAST & RELIABLY!*



Here's an all-in-one tool for prototype and small production runs that makes it simple to organize and mount circuitry in compact, planes. It quickly swages Alden terminals, eyelets, brackets and tube sockets, and punches .101" terminal holes in Alden XXP phenolic cards or any 1/16" cold punch card. You can make up circuitry turrets in minutes — complete with terminals, brackets and sockets.

Does ALL these operations:

Makes ALL these parts:

SAVE $10 on kit over individual part prices. **Contains Alden Universal Staking Tool and assortment of prepunched terminal cards, terminals, tube sockets, brackets and eyelets to get started immediately. Order Kit #42 — $49.95 complete.**

ALDEN PRODUCTS COMPANY, 5138 North Main St., Brockton, Mass.

CIRCLE NO. 96 ON INQUIRY CARD

Small, Lightweight

PRESSURE CONTROL

Operating ranges 1-20 or 1-30 PSIG.

TYPE AP-153 (STANDARD) PROVIDES SINGLE POLE CUT-IN, HIGH, SINGLE POLE CUT-IN LOW OR SINGLE POLE DOUBLE THROW OPERATION

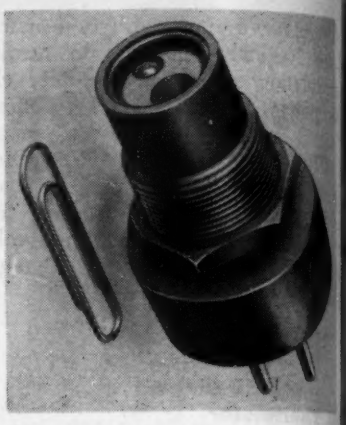
GENERAL PURPOSE (NEMA 1): For indoor use or other general applications. Pressure element—Fairprene diaphragm. Pressure connection 1/4" I.P.S. Visible calibrated dial with pointer. External adjustment. Mounting—has two mounting ears (one on each side of control) or control may be pipe mounted by means of the 1/4" bottom connection. Wiring entrance—two 1/2" openings. Internal wiring connections. Hermetically sealed mercury switch with silicone rubber covered leads.

WRITE FOR BULLETIN 02

THE MERCOID CORPORATION
4201 Belmont Ave., Chicago 41, Ill.

CIRCLE NO. 97 ON INQUIRY CARD

ELECTRONIC COMPONENTS



Miniature Infrared Photoelectric Scanner

With energy source and detector combined in a single unit only 2¼" long by 1⅛" in diameter, a new infrared photoelectric scanner, or proximity sensor, responds to metallic and non-metallic objects and provides simple and easily installed means for handling a wide variety of counting and control operations. The unit will sense objects or control-areas at distances up to two inches. Rated at 60,000 hours life when operated at five volts a-c, the solid-state detector is sturdy, sensitive, and sealed for protection against moisture, dust, or corrosive atmospheres. An infrared filter minimizes effects of ambient light. Farmer Electric Products Co., Inc., Newton Lower Falls, Mass.

Write No. 231 in Box on Inquiry Card

Ceramic Tubes

Without the use of blowers or other cooling systems, ceramic receiving tubes operate at high temperatures. Of particular importance is the fact that ceramic receiving tubes are relatively immune to high level pulses of nuclear radiation. General Electric, Owensboro, Kentucky.

Write No. 209 in Box on Inquiry Card

Silicon Tunnel Diodes

Operating temperature range of silicon tunnel diodes is —85 degree C to +[illegible] degree C. Typical negative resistance is 220 down to 39 ohms. Peak voltage is 65 mv and valley voltage is 420 mv at peak currents ranging from 1.[illegible] 5.6 milliamps. Minimum peak-to-valley ratio is 3.5:1. Hoffman Electronics Corp., Los Angeles, Cal.

Write No. 208 in Box on Inquiry Card

Solid State Power Supply

Operating from an input of 95 to 135 volts a-c, a transistorized power supply produces a continuously variable output voltage of 0-50 volts d-c and an output current of 0 to ½ amp. After an initial stabilization period of 15 sec., the output voltage does not change more than 0.07 volt about the desired setting. (Change due to internal temperature rise.) Highest ripple of 4 mv rms is at max. voltage, full load. Autotronics, Inc., Florissant, Mo.

Write No. 177 in Box on Inquiry Card

Analog-Digital Converter

One-half the size and weight of previous converters, an airborne analog-to-digital converter performs a 12-bit conversion to an accuracy of ±1 millivolt in 65 microseconds over the temperature range of −55° C to +70° C. Available also for 3 decimal digit conversion, the unit meets MIL-E-5400B and MIL-E-005272. Packaging conforms to MIL-T-19600(AER). Packard Bell Computer Corp., Los Angeles, Cal.

Write No. 175 in Box on Inquiry Card

Crystal Ovens

Designed for maximum flexibility, crystal ovens can adapt to custom requirements without complex modifications. The units combine a maximum life expectancy with minimum temperature deviation or shift and are available in a ruggedized version for high shock and vibration requirements. Voltage range is 6.3 volts to 117 volts a-c or d-c and temperature setting is +50°C to +125°C with an ambient operating range of −65°C to +120°C. Warm-up is as low as 2 minutes depending upon available power. Keystone Electronics Co., Newark, New Jersey.

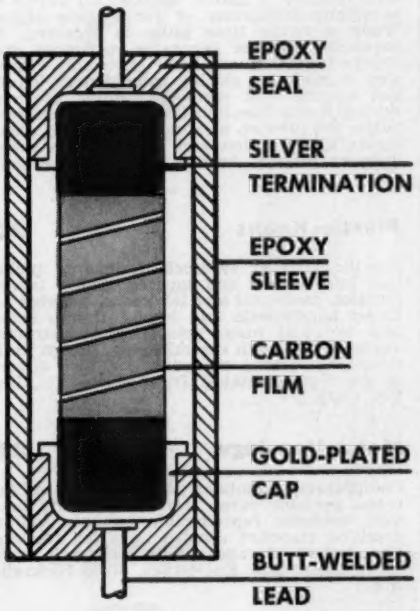
Write No. 173 in Box on Inquiry Card

DC Amplifier

Minus 5° F to 212° F is the operating temperature range for a transistorized d-c amplifier. Signals as low as 0 to 10 mv, and as high as 250 mv are permissable and under conditions of maximum gain, an input of ±10 mv will produce an output of ±5 volts. Unit withstands vibration of 20g from 15 to 2000 cps, shock of 200g, acceleration of 200g (each axis), and meets the humidity requirements of MIL-E-5272B Procedure III. United ElectroDynamics, Inc., Pasadena, Cal.

Write No. 176 in Box on Inquiry Card

NEW MEDIUM PRICED LIGHT WEIGHT CARBON FILM RESISTORS



NEW DESIGN

This new design enables Mepco to offer a moderate cost, dependable, lightweight carbon film resistor that has new features to meet the environments required by Military Specification MIL-R-10509C Characteristic B.

FEATURES

Moisture which might be absorbed during extended storage periods under high humidity conditions, cannot be transmitted to the carbon film due to the dry air space between the epoxy tube and the resistive element.

PHYSICAL AND ELECTRICAL CHARACTERISTICS

TYPE		RATING			VOLTAGE RESISTANCE			SIZE			
Mepco	MIL-R 10509C	Watts Mepco @ 125°C	Watts Mepco @ 70°C	Watts MIL @ 70°C	Max. Cont. VDC	Min. Ohms	Max. Meg. Ohms	Length	Tol.	Dia.	Tol.
EP-012	RN60B	0.125	0.25	0.125	250	5	1	.4335	±.0035	.156	±.010
EP-025	RN65B	0.25	0.50	0.25	300	10	2	.640	±.015	.240	±.010
EP-050	RN70B	0.50	1.00	0.50	350	10	5	.830	±.015	.240	±.010
EP-100	RN75B	1.00	1.00	1.00	500	10	10	1.093	±.020	.395	±.010
EP-200	RN80B	2.00	2.00	2.00	750	50	20	2.230	±.020	.395	±.010

EP SERIES

MEPCO INC.

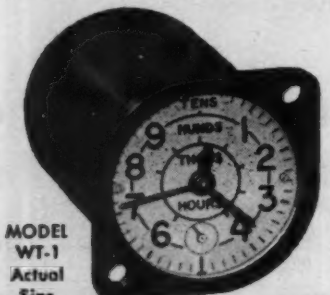
CIRCLE NO. 98 ON INQUIRY CARD

ARE YOU MEASURING . . .

- Actual life span of your equipment?
- Consumption of rated life of critical equipment or components?
- Mean-time-to failure?

You can reduce the odds against failure by constant monitoring and timely replacement of equipment approaching the end of assured performance . . . by thoughtful application of the . . .

WALTHAM
SUB-MINIATURE
ELAPSED TIME INDICATOR



MODEL WT-1 Actual Size

1 1/16" O.D. x 1 15/16" 3 OZ.
10,000 Hour Total Readout (Easily Read to Closest Hour) 400 CPS

Whether it's for reliability and life testing, design or system analysis, utilization studies . . . or to continuously monitor and log critical equipment or components . . . when you incorporate the Waltham WT-1 in your plans, you add that "measure of reliability" so important for military acceptance.

The WT-1 meets MIL-E-5272A and is available "FROM STOCK" Write Now for Bulletin 5001!

WALTHAM

PRECISION INSTRUMENT COMPANY
Waltham 54, Massachusetts

CIRCLE NO. 99 ON INQUIRY CARD

For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Range Time Decoder 228

Bulletin describes the operation of a range time decoder, a search and control device for automatic utilization of range time signals. When a range time pulse is received, the sequential counter generates an output pulse summed with binary "one" detectors. Provision is made for storing coincidence. Sequential counter and memory circuits are reset during frame identification. When preselected pulses are present, a signal is generated during frame identification and applied to a second memory circuit. Arnoux Corp., Los Angeles, Cal.

Plastic Knobs 230

Specifications of 49 stock designs to include ball knobs, oval and tapered knobs, tapered handles, push-pull and lid knobs, knurled and fluted handwheels and knobs, thumb screws and terminal nuts, pointer and instrument knobs, and certain special items. Design variations and special materials are also covered in the 8-page catalog. Dimco-Gray Co., Dayton, Ohio.

Metal Housings 236

Comprehensive catalog on a line of military cases, portable cases, transit cases and housings contains reproducible, sample vellums detailing standard constructions for combination, transit, storage and 19 inch rack equipment cases. MM Enclosures, Inc., Hicksville, N.Y.

Control Valves 233

Valves for fluid flow and condition control are covered in an 8-page booklet. Design details such as function, application, and method of actuation are covered. Complete specs are given for various types of valves including bypass, relief, check, regulator, shutoff, measuring, sequence and special purpose. United Aircraft Products, Inc., Dayton, Ohio.

Size 18 Servomotors 232

Complete with typical unit characteristics, dimensionals and torque-speed curves, a 16-page catalog includes size 18 servomotors and servomotor-rate generators for 115-volt, 60-cycle or 400-cycle operation as well as an inertia-damp unit for 115-volt, 400-cycle operation. As a further reference, a specification check list is included for use if other than standard units are required. Beckman Instruments, Helipot Division, Fullerton, Cal.

Electronic Voltmeters 247

Panel-mounting electronic voltmeters designed for continuous monitoring of critical parameters in systems and consoles are described in a folder of data sheets. The reasons for the development of the instruments are given along with a tabulation of principal specs. Metronix, Inc., Chesterland, Ohio.

Miniature Relay 243

To keep pace with the needs of missile environments and the demand for further miniaturization, a relay, described in a data sheet, conforms to all requirements of MIL-R-25018 Type II, Class B, Grade 3, is said to be 2/3 the volume of conventional designs and weighs less than 0.15 pounds. Improvement was made possible by a new magnet that combines solenoid action with an unusual adaptation of the bar principle. Cook Electric Co., Chicago, Illinois.

Vacuum Gauges 242

Use of short, firmly connected thermocouples and the absence of a suspended weld to an external heater enables a vacuum gauge to withstand great shock and vibration. The highly sensitive gauges are compensated for ambient temperature and variations in temperature. Bulletin gives principle of operation and complete specs. Hastings-Raydist, Inc., Hampton, Va.

Pressure Transducer 240

Primarily designed for airborne applications where precise pressure measurements of 0.25 percent accuracy are required over a wide temperature range, a miniature transducer's measuring element is a one-piece Ni-Span-C proving ring to which are bonded 4 precision strain gauges forming a Wheatstone Bridge. When the transducer is subjected to zero gravity conditions (as in space flight where convection cooling is non-existent) the ring acts as a heat sink and conducts heat from the resistance wires to the instrument case. Full specs are given in data sheet. Taber Instrument Corp., North Tonawanda, New York.

Protective Relays 239

Six-page catalog describing protective relays include a general design discussion on such features as induction movements, the two types of hinged armature movements available, and operation indicators. Also covered are test plugs which allow for the secondary testing of relay circuits without the alteration of links or connections on the panel. Federal Pacific Electric Co., Newark, N.J.

Pulse Generators 238

One pulse generator model provides two simultaneous pulses similar to flip-flop plate outputs but at high power levels and with independent attenuation while the other model gives single pulse, pulse pair, or pulse train modes of operation, extending applications to time measurement studies, telemetering, missile guidance coding, code word, generation, etc. Bulletin gives complete specs. Electro-Pulse, Inc., Culver City, Cal.

Solid Lubricant 237

A small sample tube accompanies a 4-page bulletin describing Molykote Type G, a grease consistency lubricant that reduces galling, seizing and metal pickup in high pressure and temperature applications. Instructions for applying the lubricant are presented. The Alpha-Molykote Corp., Stamford, Conn.

Miniature Bearings 241

Instrument bearings have been specifically designed to replace precision ball bearings in a wide variety of applications where requirements do not justify the cost of expensive ball bearings, but here precision instrument standards of tolerances, life and low friction must be maintained. Selection guide includes a simpified method of determining allowable bearing loads for any size bearing and any shaft speed. Northfield Precision Instrument Corp., Island Pk., N.Y.

Stainless Steel 25

Revised data chart provides analyses specifications for 58 different types of stainless steel. It covers all 40 standard AISI grades plus specials including the widely accepted precipitation hardening grades 17-4, 17-7 and 15-7 MO.

Nearest corresponding SAE and AMS designations are cross-indexed with AISI grades for added convenience. Peter A. Frasse & Co., Inc., New York, N.Y.

Recording Supplies 249

Folder describes chart papers, writing styli and other supplies for all models of company's direct writing recording equipment. Samples of chart papers are included and typical recording traces in the three basic techniques—ink, electric or thermal demonstrate the uniformity, clarity and reproducibility to be expected. Brush Instrument, Div. of Clevite Corp., Cleveland, Ohio.

Coils 248

By using thin bobbins and other special techniques detailed in a bulletin, relay coils can be produced with more ampere turns within a given volume, while holding resistance level. Readers requesting this "case history" will automatically receive five more coil problem case histories now being documented. Tur-Bo Jet Products Co., San Gabriel, Cal.

Recorder/Reproducer 386

Brochure describes two digital tape recorder/reproducer transport systems, one operating at speeds up to 30 ips and the other 150 ips. A detailed description of operating characteristics and specifications for both units are included. Consolidated Electrodynamics, Pasadena, California.

Solenoid Valves 326

3-position, 4-way dual solenoid valves, instantaneous in operation, use only two moving pilot cores and four flexing diaphragms. Design eliminates spools or closely fitted parts, sliding glands, stuffing boxes, stroke settings and seat regrinding. In the closed center position, when both solenoids are deenergized, flow is blocked to all orifices. Valve locks the cylinder piston at any point of the stroke. Automatic Switch Company, Florham Park, New Jersey.

Velocity-Damp Servomotor 323

Size 18 servomotors follow high-speed and/or high-gain input signals without oscillation. Damping is easily adjustable, and can be locked in at any desired setting. Helipot Division of Beckman Instruments, Inc., Fullerton, Calif.

Solenoids And Stepping Motors 322

Eight-page application guide on rotary solenoids, selectors and stepping motors contains specific physical, performance and environmental data on more than 250 different models. Only half the size of ordinary units, a highly efficient rotary solenoid is said to be capable of developing twice as much power. A versatile, high-precision, bi-directional stepping motor develops at least three times greater torque than comparable devices can provide. G. H. Leland, Inc., Dayton, Ohio.

Retainer Bearing 325

Combining the high-speed qualities of laminated phenolic and the high strength of aluminum alloy, "T" retainer ball bearings operate in temperatures up to 300 degrees F for continuous operation, and for short periods to 350 degrees F. Design permits maximum speeds up to 110,000 rpm with grease lubrication under moderate loads and moderate temperatures. Barden Corporation, Danbury, Connecticut.

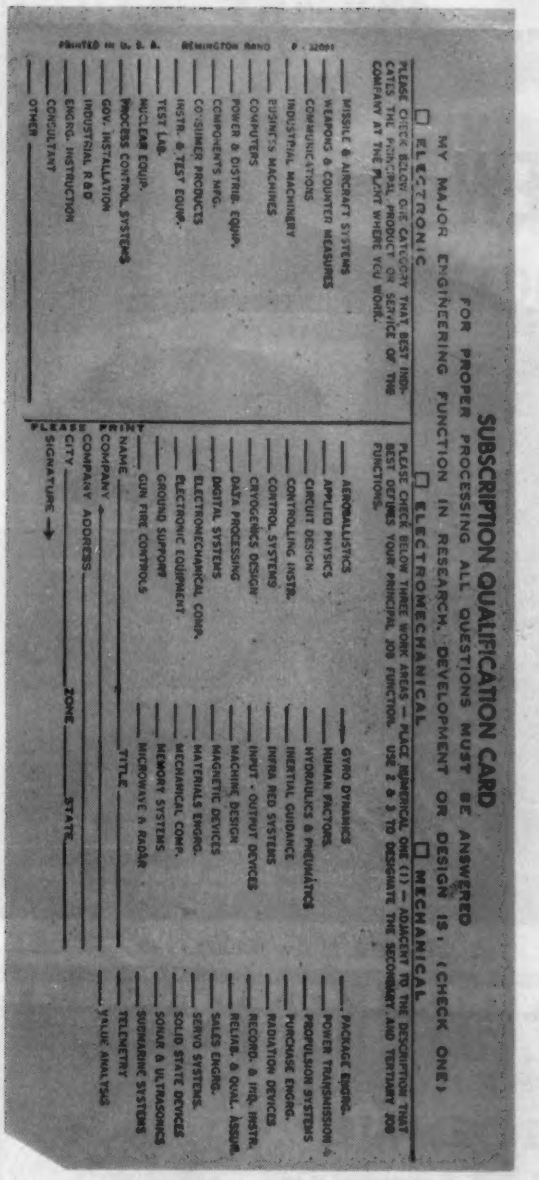
Servo Components 330

New manufacturer of precision servo components presents data on control and torque synchros and resolvers. Covers size 23, 60 and 400-cycle units. Vernitron Corp., New York, New York.

Printed Circuit Grid Boards 331

With grid boards made from Fotoceram, an inorganic glass ceramic, designers can cut circuit patterns on a grid, then etching make prototype printed circuits in 15 minutes. Process consists basically of laying away excess copper with acid. Corning Glass Works, Corning, New York.

watch



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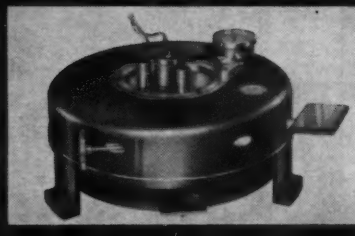
NEW design PRECISION ANGULAR DIVIDER

available from stock

Positions synchros and resolvers with less than 20 sec. error.



Accepted and utilized for 3 years by the major synchro quality control facilities, the Theta Angular Divider has become a standard of the industry. It is the only positioning mechanism which guarantees less than a 20 sec.-of-arc composite error at the point of contact with the synchro shaft. Ready to use — additional fixturing is not required. Adapters to accommodate Size 8 through Size 37 are stocked.

A complete Technical Bulletin is available.

Theta INSTRUMENT CORPORATION

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USE **BODINE K-2 Motors**

..for instruments, timing devices control apparatus and similar applications

- only 2⅛" high
- totally enclosed
- 1/2000 to 1/500 horsepower
- with or without speed reducers (spur or helical gearing)
- synchronous or non-synchronous
- available from your distributor's stock

FREE Bulletin "S-2" | covers Bodine K-2 Motors, and other stock motors.

BODINE fractional horsepower MOTORS

Bodine Electric Co., 2530 West Bradley Place, Chicago 18, Ill.

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Four-page brochure on flexible couplings contains lateral, axial, and torsional deflection data. Coupling materials are aluminum with beryllium copper leaves. To provide a design with maximum flexibility and zero backlash. Naugler Engineering Inc., Beverly, Mass.

Magnetostrictive Delay Lines

Extensive information on the theory of operation of fixed and variable magnetostrictive delay lines is available. Listed are fixed line characteristics, delay ranges, tap variable delay lines, adjustments, impedance, temperature and associated circuitry. Control Electronics Co., Huntington Station, L.I., N.Y.

Integrating Gyros

A group of miniature, floated rate integrating gyros fall into two general classifications, those used primarily in stable platforms and those employed principally in fire control and autopilots. Common to all of the gyros detailed in a booklet are external adjustment features which permit maximum ease in fabrication and calibration. These include a mechanical mass unbalance adjustment along spin and input axes, a mechanical fixed trim adjustment, and an adjustment for spin axis alignment, all of which can be used after gyro assembly and while the gyro is undergoing test. These adjustment capabilities, together with a relatively simple design result in gyros which can be built and calibrated with ease and which demonstrate unusual reliability. Kearfott, Div., Little Falls, New Jersey.

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Adhesives and Laminates

Included in a bulletin is a temperature chart that indicates the upper and lower service limits for each adhesive and laminating material described. Putties, resins and sandwich core materials are also listed. Narmco Resins & Coatings Co., Costa Mesa, Cal.

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Ann Arbor, Michigan